ASSESSMENT OF FACIAL EXPRESSION ASYMMETRIES
UTILIZING DIGITIZED IMAGE ANALYSIS
AND IMPRESSIONISTIC RATINGS

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
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Facial expressions encompass a prominent aspect of
emotional behavior. Prior research has generally found that
the left hemiface is more expressive than the right hemiface
while posing emotional expressions. There are three major
proposals that account for expressive asymmetries and they
are the Right Hemisphere, Valence and Facial Mobility
hypotheses. Research reporting expressive asymmetries has
primarily relied upon subjective ratings, while studies
failing to replicate these findings have generally utilized
a more objective measurement system.

In an effort to find an "objective" method which has
the sensitivity to uncover possible facial asymmetries,
digitized image analysis has been proposed as an alternative
approach. In this study, digitized image analysis was used

to scrutinize videotaped images of posed facial expressions. Facial movement was inferred from changes in pixel intensities during facial expressions. The degree of movement for each hemiface was measured during emotional and nonemotional expressions. Subjective ratings were also obtained and compared with the digitized image analysis.

The primary questions of interest were whether hemiface asymmetries in dynamic expressions would be present using digitized image analysis and to what degree are subjective ratings consistent with the results of the digitized data. Other major questions of interest were whether expressive biases conform to our current knowledge of neuroanatomy and which of the major competing hypotheses would be most consistent with the findings of the digitized analysis.

The results indicated the presence of hemifacial expression asymmetries using digitized image analysis. The pattern of lateral biases differed depending upon the portion of the face examined. In the lower face, negative expressions were left-biased and the positive expression displayed a right-sided trend. The nonemotional expressions did not suggest a clear pattern of asymmetry. In the upper face, nearly all of the emotional and nonemotional expressions were right-biased. Expressive asymmetries were

more consistent with the Facial Mobility hypothesis in the upper face and the Valence hypothesis in the lower face. In contrast, the subjective ratings indicated that no emotional expression was asymmetrical. There were significant methodological weaknesses associated with the subjective ratings in this study. The discussion focuses on the implications of the digitized data.

INTRODUCTION

Defining Emotion

The study of emotion has been an integral aspect of psychology and philosophy since the beginnings of these disciplines. One of the most enduring contributions of the founding father of American psychology, William James, is his theory of emotions. Despite the attention emotion has received, a consensus has yet to be developed regarding the definition of emotion. Most definitions tend to include four major components: physiological arousal, motor activity, subjective feeling and an evaluative capacity (Borod, 1993; Bowers, Bauer and Heilman, 1993). Fehr and Russell (1984) noted, however, that attempts to incorporate these four components within a definition has failed to produce one which precludes other cognitive processes, such as attitudes or motives. Consequently, they concluded that a classical definition of emotion is likely unattainable.

Despite the difficulty of delineating an airtight definition of emotion, vigorous scientific investigation has continued. In general, the question has been addressed by focusing on one or more of the aforementioned components of physiological arousal, motor activity, subjective feeling and evaluative ability. While there may be substantial

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agreement concerning these features, the role of cognition is hotly debated. For example, Zajonc (1980) has proposed a distinct emotional system that does not require cognitive processes to be activated. He further asserts that the affective reactions occur more rapidly than the more analytical, cognitive processes.

The ideas of Zajonc and other similarly minded theorists share some aspects of the James (1892) view of emotions which emphasizes the role of primitive perceptual analysis leading to autonomic and motor responses. Zajonc's views (1980), however, differ from those of James (1892) in that subjective emotional experience is posited to occur almost simultaneously with the rapid affective perceptual system. James (1892), on the other hand, argued that subjective feeling developed after one sensed a change in one's autonomic system.

In this regard, James' (1892) theory is more consistent with the proposals that favor a cognitive role in emotional experience (Schacter and Singer, 1962; Lazarus, 1990). They suggest that there cannot be emotion without cognition, and thus, a separate entity of emotion is not possible. For instance, Schacter and Singer (1962) have asserted that cognitive attributions must exist prior to the subjective feeling of emotion, and it is through the feedback process between cognition, physiological arousal and motor activity that the subjective feeling of emotion is experienced.

In support of their proposition, they reported an experiment in which subjects injected with epinephrine experienced emotion only if an emotional stimulus was present in the environment. They argued that one's physiological arousal must be attributed to an emotional stimulus in order for the subjective experience of emotion to develop (Schacter and Singer, 1962). Consistent with this viewpoint is evidence suggesting that cognitive decisions are made more rapidly than ones requiring an affective response. In a review of a series of studies, Feyereisen (1989) concluded that when examining a set of stimuli, subjects are slower at making affective decisions than cognitive ones, a conclusion which contradicts Zajonc's (1980) position that the affective system operates more rapidly than the cognitive system.

On the other hand, there are several lines of evidence that are inconsistent with the cognitive perspective on emotion. For example, several studies have described seizure patients who experience the sensation of an emotional state, usually fear, at the initial stages of a seizure (Strauss, 1989). The fact that these patients experience other emotions besides fear suggests that this phenomena is not the result of their sensing an impending seizure. Furthermore, seizure patients who have had their amygdala electrically stimulated have also described various emotional sensations (Halgren, Walter, Cherlow and Crandall,

1978; Gloor, Olivier, Quesney, Anderman and Horowitz, 1982).
In addition, single cell recordings in the amygdala of
primates have found that certain cells are particularly
sensitive to emotional stimuli, or more specifically,
emotional faces (Leonard, Rolls and Wilson, 1985). This
might provide a link between the evaluation and the
experience of emotion (LeDoux, 1989). Taken together, these
findings suggest that there are neurons which are
specialized in producing subjective emotional states and
that cortical involvement may not be necessary for the
experience of emotion.

Lazarus (1990) has asserted that the conflict between
the cognitive and non-cognitive viewpoints of emotion
originates in a simplistic understanding of cognition. He
disputes the commonly held notion that cognitions are solely
the function of conscious processes. He argues, instead,
that cognitions include even basic mental operations that
are calculated without the awareness of the individual
(Lazarus, 1990; Buck, 1993) In defense of his position,
there exists substantial evidence of a dissociation between
implicit and explicit learning on semantic memory tasks
(Schacter, 1987; Squire, 1987). A dissociation of implicit
and explicit memory indicates that one can develop a
cognitive representation of a stimulus and not be aware of
it.

Buck (1993) contends, however, that if one accepts the broad view of cognition advanced by Lazarus (1990), then it becomes increasingly difficult to distinguish cognition from perception even at the most elemental levels. If cognition encompasses nearly all forms of perception, then there is little that separates the cognitive and non-cognitive viewpoints (Buck, 1993). Consequently, one may wonder whether the debate on the definition of emotion is actually a debate on the meaning of cognition (Buck, 1993).

With this in mind, it is conceivable that the cognitive/perceptual component to emotion is basically equivalent to the evaluative component of emotion. Accepting the view that emotion consists of several components has been the predominant opinion among psychologists and has been associated with more fruitful research by allowing scientists to focus on particular elements, rather than grapple with all aspects of emotion. The focus of this research endeavor is on the motor activity component of emotion as it involves the production of emotional facial expressions.

The motor activity component of emotion, as well as emotion in general, has both biological and psychological dimensions. As a result, some researchers have approached the question of emotion from a more psychological or cognitive perspective while others have addressed it from a more biological viewpoint. Because neuropsychology attempts

to integrate these perspectives, research from a neuropsychological approach may prove useful in improving our understanding of emotion (Heller, 1990).

<u>Neuropsychology of Emotion</u>

An assumption of the neuropsychological approach is that the central nervous system is organized such that specific anatomical entities control distinctive aspects of an organism's response repertoire. These specialized operations include cognition, attention, emotion, arousal, etc. An overwhelming array of evidence has accumulated such that this assumption is no longer seriously debated within the neuroscientific community (Heller, 1990). One of the basic anatomical divisions of the primate brain is that of the left and right hemispheres. It is well established that the two hemispheres each have capabilities for which they are undoubtedly specialized (McGlone, 1980; Bradshaw and Nettleton, 1981; Heilman and Valenstein, 1993). A wide body of evidence indicates that the left hemisphere is involved in the processing and production of verbal information. Many nonverbal processes, however, appear to be under the control of the right hemisphere. The most notable example is that of interpreting and generating spatial configurations and relationships (McGlone, 1980; Bradshaw and Nettleton, 1981; Benton and Tranel, 1993).

In the past 25 years, research has suggested an additional specialization of the right hemisphere involving

emotion. As previously mentioned, there are several components associated with emotions including physiological arousal, motor activity, subjective feeling and a perceptual/cognitive function. Neuropsychological research indicates that these elements may be dissociated and that support for a right hemisphere advantage depends upon the component studied (Tucker, 1993). Scientific inquiries involving the evaluative (perception/cognition) and expressive (motor activity) aspects of emotion have suggested a greater contribution of the right hemisphere system (Bowers and Heilman, 1984; Borod, 1993; Heilman, Bowers and Valenstein, 1993). Consequently, the right hemisphere has been hypothesized to be specially equipped to analyze and interpret emotional stimuli (e.g. facial expression, tone of voice) as well as express these same signals. The results which have been consistent with a right hemisphere specialization have more often been found associated with the evaluation or interpretation of emotion, whereas the evidence for a similar specialization in the production or expression of emotion is less conclusive (Bryden and Ley, 1983; Borod and Koff, 1984; Bruyer, 1986).

Evaluation of Nonverbal Emotional Signals

Two distinct approaches have been used to make inferences about brain involvement in the processing of nonverbal emotional stimuli. The first approach has relied on evidence obtained from brain-impaired subjects and the

second has utilized normals while participating in tasks in which stimuli are presented to a specific hemisphere. Two early studies using the former approach were conducted by Heilman and colleagues (Heilman, Scholes and Watson 1975; Tucker, Heilman and Watson, 1977). They introduced propositionally neutral sentences to right hemisphere diseased (RHD) subjects, left hemisphere diseased (LHD) subjects and normal controls. The prosody of the sentences, however, varied between four different emotions. RHD subjects were found to be impaired in their ability to identify the emotional prosody. Ross (1981) also reported RHD impairment in their ability to comprehend emotional prosody.

Weintraub, Mesulam and Kramer (1981), on the other hand, proposed that RHD difficulty processing emotionally intoned speech was the result of a general prosodic defect, rather than one specific for emotional prosody. Consistent with the view of Weintraub et al. (1981), Van Lancker and colleagues have reported that RHD subjects have difficulty discriminating and recognizing familiar voices (Van Lancker and Kreiman, 1988; Van Lancker, Kreiman and Cummings, 1989). Heilman, Bowers, Speedie and Coslett (1984) also found that both LHDs and RHDs were disrupted in their ability to understand nonemotional prosody; however, RHDs were significantly more impaired than LHDs in their ability to comprehend emotional prosody. Their findings, which were

corroborated by Bowers, Coslett, Bauer, Speedie and Heilman (1987), suggest that a general prosodic defect may be the consequence of cortical damage to either hemisphere, yet RHD specifically enhances the impact of this defect for processing emotional prosody.

Further research with focal lesion patients has indicated that a right hemisphere specialization for processing affective stimuli is not limited to the auditory channel. Dekosky, Heilman, Bowers and Valenstein (1980) assessed RHD and LHD subjects capacity to name, select and discriminate emotional faces. They found that although LHD subjects had difficulty with some tasks, RHD subjects were more impaired. In addition, Cicone, Wapner and Gardner (1980) also reported that RHDs had difficulty processing facial emotions. To rule out the possibility that an RHD impairment in emotional face recognition was secondary to a general defect in visuo-spatial processing, Bowers, Bauer, Coslett and Heilman (1985) conducted a further study of facial affect processing. They statistically equated RHDs, LHDs and controls on a measure of visuo-spatial ability and found that RHD patients remained impaired (relative to LHD and controls) in their ability to distinguish the emotional category of a facial expression. Their findings suggest that there is a right hemisphere advantage for processing emotional faces in addition to a specialization for spatial-configuration analysis.

Along with studies of brain damaged subjects, additional research has been conducted using normals. Through dichotic or monoaural listening tasks (Safer and Leventhal, 1977; Ley and Bryden, 1982) and tachistoscopic studies (Ley and Bryden, 1979; Safer, 1981; Strauss and Moscovitch, 1981), further evidence has accumulated that is consistent with a right hemisphere advantage in the processing of nonverbal affective signals. In general, these studies have supported a right hemisphere specialization; however, there has been some discrepancy in the findings.

For example, Lavadas, Umilta and Ricci-Bitti (1980) found that only women displayed a right hemisphere/left visual field (LVF) advantage for naming emotional faces. Safer (1981) also found sex differences in visual field superiority for matching emotions, although it was males, rather than females who displayed the LVF advantage. In a review of the literature, Bryden and Ley (1983) reported that of the investigations finding a gender effect for lateralization, neither gender was consistently associated with greater lateralization for processing visual, affective material.

In addition to possible sex effects, there is some evidence that the valence of the target emotion impacts the visual field advantage. For example, Reuter-Lorenz and Davidson (1981) found a LVF advantage for positive (happy)

affective material and a right visual field advantage for
negative (sad) expressions. Other researchers, however,
have not reported an association between visual field
superiority and emotional valence (Duda and Brown, 1984;
Bryson, McLaren, Wadden and MacLean, 1991). Thus, neither
the sex of the subject nor the valence of the emotion were
consistently associated with visual field advantages. Taken
together, the majority of studies using normals and brain-
impaired subjects across several channels of perception is
consistent with a right hemisphere specialization in the
evaluation of nonverbal affective signals.

<u>Valence Hypothesis</u>

The results of the Reuter-Lorenz and Davidson (1981)
study were inconsistent with most research in this area,
yet, they were compatible with an alternative hypothesis
involving a hemispheric specialization for emotion.
Proponents of this, the Valence hypothesis, originally
proposed that the left hemisphere is specialized for
positive emotions and the right hemisphere for negative ones
(Davidson, Schwartz, Saron, Bennett and Goleman, 1979).
Support for the Valence hypothesis is based both on clinical
observations of brain-impaired patients (Gainotti, 1972) as
well as electroencephalograms (EEG) from either depressed
patients (Robinson and Szetela, 1981) or normals undergoing
mood induction (Davidson et al., 1979). In addition,
studies in which subjects have had one hemisphere of the

brain anesthetized (via sodium amytal injections into the contralateral femoral artery) have responded in a manner consistent with the Valence hypothesis (Lee, Loring, Meador and Flanigin, 1987).

Gainotti (1972) reported that the affect of LHD patients appeared to be more depressed and the affect of RHD patients seemed to be either neutral or euphoric. Robinson and coworkers (Robinson and Szetela, 1981; Robinson, Kubos, Rao and Price, 1984) have found that post-stroke depression is more often associated with left hemisphere lesions and the severity of the depression increases with greater damage concentrated in the anterior portion (i.e. left frontal). In regards to depressed patients, EEG data indicates that there is a greater increase in right versus left frontal activity (Schaffer, Davidson and Saron, 1983). Furthermore, Perris (1975) has found that the severity of the depression is correlated with the activity level in the right frontal region. Similarly, normals receiving mood induction display greater right hemisphere activity in the sad or depressed condition and greater left hemisphere activity in the positive condition (Davidson et al., 1979). Finally, the affective demeanor of those whose left hemisphere has been anesthetized is generally negative (anxious and frightened), while those whose right hemisphere has been anesthetized is generally neutral or euphoric (Terzian, 1964; Lee et al., 1987).

Because research supportive of the Valence hypothesis has generally been associated with the experience of emotion and research consistent with the RH hypothesis has frequently been connected to the evaluation of emotion, Davidson has proposed a model which accounts for the discrepant findings between the evaluation and the experience of emotion (Fox and Davidson 1984; Davidson, 1993). His model not only distinguishes between these components of emotion, but it also challenges the core assumptions of the Valence hypothesis. He argues that what appears to be differences in emotional valence may actually be differences in a more fundamental system. He proposes that this system is based upon tendencies to approach and withdraw such that the left hemisphere is involved with approach behaviors and the right hemisphere is associated with avoidant behaviors.

Whether affective valence or approach/withdrawal is more fundamental remains debatable as does the Valence hypothesis in general. There have been other challenges to the Valence hypothesis. For example, Heilman and Watson (1989) have proposed an alternative model based on a right hemispheric specialization of both arousal and the evaluation of nonverbal stimuli and a left hemispheric specialization for the interpretation of verbal stimuli. Their model suggests that hemispheric activation as measured by EEG is related to whether a stimulus is arousing and

requires verbal or nonverbal processing. Thus, it is the arousing aspects of an affectively negative experience, rather than its emotionality that is associated with heightened RH activity.

Expression of Emotional Signals

Hemispheric specializations may not be limited to the evaluation of nonverbal emotional signals. A hemispheric advantage for the production of emotion may also exist. As previously reviewed (see section on evaluation of nonverbal emotional signals), there are several different channels through which emotional expression can occur. Hand movements or body posture can convey an emotional message. Facial expressions are also a rich source of affective information as is the intonation of speech. Consequently, many of these channels have been utilized to explore hemispheric advantages in the expression of emotion.

For example, Tucker et al. (1977) investigated the performance of brain injured patients on a task which requested affectively intoned speech. The results indicated that the speech of RHD subjects was particularly flat and the production was severely impaired as compared to controls and LHD patients. Similarly, Ross (1981) reported that RHD patients were impaired in their ability to convey the emotional meaning of a sentence through intonation. Borod, Welkowitz et al. (1990) as well as Shapiro and Danly (1985) have also found that RHDs display deficits in prosodic

expressivity. Cancelliere and Kertesz (1990), however, have reported results inconsistent with the majority of the research on prosodic expression in focal lesion patients. In response, Borod (1993) noted that Cancelliere and Kertesz's (1990) studied patients with acute lesions which may have contributed to their anomalous findings. In general, research indicates that the right hemisphere may be critical for the production of affective prosody.

Further analysis has focused on the facial channel of emotional expression. A substantial collection of studies during the past three decades have explored a possible right hemisphere advantage in the production of voluntary and spontaneous facial expressions. The results have generally been inconsistent in their support of a right hemisphere specialization for the production of facial emotions. The rest of the introduction will be devoted to the exploration of this body of research and its seemingly conflictual findings.

Methodological Issues in Facial Expression Research

Prior to reviewing this literature, however, the basic set-up of this research will be described. The typical experiment begins with subjects producing facial expressions in response to a verbal command (e.g. show me how you would look if happy). Subjects may be asked to generate a facial expression that matches the emotional content of a cartoon drawing (e.g. person receiving an award) or a verbal

description of an emotional scene (e.g. the university has just informed you that your daughter has made straight A's). In addition, subjects may be requested to mimic the facial expression of another person in a photograph. The room is usually well lit so that investigators are able to videotape or photograph the subjects' facial expressions. Subjects may or may not be informed that they are being videotaped or photographed. Facial expressions produced in these conditions are considered posed or voluntary.

In other designs, subjects may view film clips or recall memories from their past and their spontaneous reactions are unobtrusively recorded. The key aspect to these elicitation procedures is that subjects are never asked to make facial expressions. Thus, the expressions in these conditions are considered to be spontaneous or involuntary. The distinction between voluntary/posed and involuntary/spontaneous is important since different neural circuitries are thought to underlie each (for review, see Rinn, 1984).

In brief, the neural pathways responsible for spontaneous expressions are extrapyramidal and involve the subcortex, possibly originating in the thalamus or hypothalamus (Poeck, 1969). The neural pathways associated with posed expressions, on the other hand, are pyramidal and receive both direct and indirect input from the motor cortex (Noback and Demerest, 1975; Brodal, 1981). Evidence for a

dissociation between these expressive systems comes from patients with motor cortex lesions who cannot produce voluntary emotional expressions contralateral to the lesion, yet do display spontaneous emotional expressions without asymmetry (Monrad-Krohn, 1924; Rinn, 1984). In addition, patients with Parkinson's disease appear to have flat affect lacking a spontaneous emotional quality, yet can mimic emotional expressions on command (Kahn, 1964; Rinn, 1984; Pizzamiglio, Caltagirone and Zoccolotti, 1989). Further evidence of a dissociation can be found with patients receiving facial nerve surgery and with patients suffering from pathological laughing or crying (Poeck, 1969; Rinn, 1984; Pizzamiglio et al., 1989).

Because pyramidal and extrapyramidal tracts differ to the degree in which they innervate the ipsilateral and contralateral sides of the face, it is critical that researchers differentiate between the two systems (Kahn, 1964; Rinn, 1984; Thompson, 1985). Neuroanatomical evidence suggests that there is contralateral innervation associated with posed expressions (Crosby and Dejong, 1963; Kahn, 1964; Rinn, 1984), although the pattern of innervation differs between the upper one-third of the face and the lower two-thirds of the face. According to Kuypers (1958), there is a bilateral pattern of innervation of the forehead and brow with an apparent equal distribution of contralateral and ipsilateral fibers. The lower portion of the face is

believed to be primarily innervated by fibers from the contralateral hemisphere. The innervation pattern related to spontaneous emotional facial expressions appears to be bilateral, although this may be debatable (Thompson, 1985; Pizzamiglio et al., 1989). Thus, inferences about hemispheric cortical activity based upon facial asymmetries is more consistent with neuroanatomical evidence for posed expressions than spontaneous ones.

Once a facial expression is elicited, whether spontaneous or posed, a variety of methodological differences exist in terms of how or what portions of the face are captured for eventual measurement and rating of emotionality. Some studies have utilized the whole face in its natural form and asked raters to judge which side is more expressive (Borod, Caron and Koff, 1981; Borod and Koff, 1983). The whole face image represents the most ecologically valid representation, since it is a reproduction of an actual face. The disadvantage of presenting a normal image of the whole face, however, is the lack of control for possible visual field preferences of the raters. In other words, one side of the face may receive greater attention or superior processing due to the visual field advantages of the raters. Therefore, ratings favoring one side of the face may reflect an asymmetry in the visual processing of emotional stimuli, rather than an expressive asymmetry of the posers. Studies have indicated that there

is a left visual field bias for processing emotional facial expressions (Gilbert and Balkan, 1973; Bennett, Delmonico and Bond, 1987).

To adjust for visual field advantages, researchers have created mirror reversals of emotional expressions (Borod, Koff, Lorch, Nicholas & Welkowitz, 1988; Moreno, Borod, Welkowitz and Alpert, 1990). Mirror reversals are the actual whole face with the exception that each side of the face is repositioned to the opposite side. If used alone, a mirror reversal is also susceptible to a rater's visual field bias. However, if an equal number of normal whole face images and mirror reversals are presented, a visual field advantage is negated since the bias is distributed equally to each side of the face.

Another approach has been to present each hemiface (one side of the face) separately. Investigations which present each hemiface alone reduce the distracting effect of the other hemiface, yet these studies sacrifice the real world impression of a whole face. Other alternative methods of presentation include the creation of hemiface chimerics (Campbell, 1978; Levy, Heller, Banich and Burton, 1983) and hemiface composites (Sackeim, Gur and Saucy, 1978; Moreno et al., 1990). Hemiface chimerics are constructed by creating a mirror reversal of one side of the face (e.g. left hemiface) prior to the initiation of an expression and combining it with the same hemiface at the peak of the

expression. In effect, a rater would see one half of a face making an expression while the other half remains in a neutral pose (both halves originate from the same side of the face). The advantage of this procedure is that the degree of facial movement for a particular hemiface can be compared to its initiation point. The disadvantage is that the expression has little similarity to a natural expression.

Hemiface composites are similar to hemiface chimerics in that one side of the face is copied and repositioned to the other half of the face forming a whole face constructed from only one half of the face. They are different in that each side is an exact duplication of the other half. Hemiface composites have the advantage of reducing distraction effects of the competing side and increasing the sensitivity to small differences by effectively "doubling the hemiface." On the other hand, composite images are frequently described as bizarre in appearance, and thus, may skew raters' judgments due to a lack of ecological validity.

The choice between the aforementioned approaches has generally varied as a function of the subject population. Whole face ratings and mirror reversals have been the preferred choice with brain-impaired subjects. Hemiface composites are generally not used with brain-impaired subjects because of the frequent occurrence of a hemiface paresis (partial paralysis of one side of the face)

contralateral to the side of the lesion. In addition, bilateral innervation of the face for spontaneous expression and partial bilateral innervation of the face for posed expressions suggests that a reduction in facial expressiveness should be, at least, partially distributed to both sides of the face. With normal subjects, any of the above means of presentation can and have been utilized with the advantages and disadvantages previously discussed.

The next issue is the manner of recording and presentation. Much of the research on facial expressions has relied upon still images, regardless of whether the initial images were videotaped or photographed. A few studies by Borod and colleagues have presented videotaped facial images in a dynamic fashion (Borod et al., 1981; Borod and Koff, 1983; Borod, Koff and White, 1983).

Another research issue involves the number and valence of the target expressions. The most commonly elicited emotional expressions include happy, sad, angry, fear, disgust and surprise. Some studies have elicited all of these emotions (Sackeim et al., 1978; Braun et al., 1988), while most have targeted only a few (Campbell, 1978; Sirota and Schwartz, 1982; Dopson, Beckwith, Tucker and Bullard-Bates, 1984). Several studies have elicited only one target emotion (Heller and Levy, 1981; Wylie and Goodale, 1988).

For investigations relying on an impressionistic judgment of hemiface differences, the dimensions of the

rating scale is an important variable. Some studies have requested judgments of facial asymmetry (muscle movement bias to one side of the face: Borod and Caron, 1980; Borod and Koff, 1983; Borod et al., 1983) or level of intensity (either undefined: Sackeim et al., 1978; or defined as muscle movement: Borod et al., 1981; Moreno et al., 1990) of an expression. Two forms of accuracy have been utilized and defined in terms of whether the subjects' expression matches the target emotion (category accuracy) or is consistent with the valence of the target emotion (Kent, Borod, Koff, Welkowitz and Alpert, 1986; Borod et al, 1990). Other rating dimension scales such as appropriateness (Borod, Koff, Lorch and Nicholas, 1986; Caltagirone et al., 1989; Weddell, Miller and Trevarthen, 1990) and expressivity (Dopson et al., 1984; Mammucari et al., 1989) have been utilized by some, yet were undefined. Appropriateness of an expression in some studies, however, has been defined as its consistency with the emotional character of the elicitor stimuli (Borod et al., 1988; Martin, Borod, Alpert, Brozgold and Welkowitz, 1990). Finally, Blonder, Burns, Bowers, Moore and Heilman (1993) had raters judge expressivity with anchor referents on a seven-point Likert scale.

For the analysis of the facial expressions, approaches have varied considerably across studies and basically fall into two distinct categories--one involving holistic, impressionistic ("subjective") ratings by trained and

untrained judges and the other involving more "objective"
methods. There have been an assortment of techniques
utilized for both subjective and objective methods. For
example, Borod and colleagues have relied upon judges who
rate the level of intensity (muscle movement) or asymmetry
(muscle movement bias to one side of the face) of a given
emotional facial expression (Borod and Caron, 1980; Borod et
al., 1981; Borod and Koff, 1983; Moreno et al., 1990). She
and other investigators have also had their judges rate the
appropriateness or determine the accuracy of an expression
(Borod et al., 1988; Weddell et al., 1990; Borod et al.,
1990; Richardson, Bowers, Eyeler and Heilman, 1992). Many
of the studies have instructed the raters to utilize likert-
type scales for the emotional dimension of interest (Sackeim
et al., 1978; Borod et al., 1981, Moreno et al., 1990).
Other studies have used a forced choice procedure in which
the rater must choose which of two images appears more
intense, asymmetrical, etc. (Campbell, 1978; Rubin and
Rubin, 1980) All of these methods are subjective and they
emphasize the judges' holistic impression of the facial
stimuli.

In contrast to these holistic emotional rating
approaches, there have been several attempts at a more
objective analysis of facial expressions. Both Izard and
Ekman have developed methods in which discrete muscle
movements of the face are measured by trained raters (Ekman

and Friesen, 1978; Thompson, 1985). Each of these systems require their raters to undergo intensive training to detect isolated muscle contractions of the entire face or discrete regions of the face and to estimate the intensity of the contraction. Thus, a quantified measure of facial activity can be estimated by summing the intensity scores from each discrete facial unit. The Facial Action Capture System (FACS) developed by Ekman is more widely used and is considered more comprehensive than the Maximally Discriminative Facial Movement Coding system (MAX) created by Izard (Rinn, 1984; Thompson, 1985).

An additional approach involves surface electromyographic (EMG) recordings of the face to obtain a more objective measure of facial activity (Schwartz, Ahern and Brown, 1979; Sirota and Schwartz, 1982). Wylie and Goodale (1988) have employed yet another approach. In their case, they utilized digital image analysis in which changes in spatial positioning of several facial markers were calculated. The markers were placed on the nose, cheeks and each side of a subject's lips. The difference in marker position from the beginning until the peak of an expression was calculated to provide a measure of facial activity.

Production of Facial Expressions

Research on emotional facial expressions is generally divided into studies which explore spontaneous (involuntary) expressions and studies which examine posed (voluntary)

expressions. Despite the bilateral innervation associated with involuntary emotional expressions (Thompson, 1985; Pizzamiglio et al, 1989), researchers have studied spontaneous expressions in order to make inferences about hemispheric specialization (Dopson et al., 1984; Borod et al., 1990; Blonder et al., 1993). The approach to these studies has generally included a comparison of right and left brain diseased subjects with normal controls or a comparison of left and right hemiface activity for non-impaired subjects.

In the case of hemiface activity, differences are thought to be the result of superior processing and greater involvement of the contralateral hemisphere. The assumption being that the fibers innervating the face are crossed, and therefore, it is the contralateral hemisphere that is responsible for hemiface activity. In regards to spontaneous expressions, however, this supposition may be incorrect. As mentioned previously, there is evidence that the innervation pattern associated with spontaneous expressions is actually bilateral in nature (Thompson, 1985; Pizzamiglio et al., 1989).

Spontaneous Expressions in Normals: Laterality Studies

Research assessing facial asymmetries during spontaneous emotional expression has generally found that the left hemiface is more active and expresses emotions more intensely than the right. For example, Borod et al. (1983)

conducted a study in which positive and negative slides were shown to subjects to elicit emotional facial expressions. Three trained judges rated the asymmetries of dynamically presented whole faces. Results indicated that male subjects displayed a significant left-sided asymmetry for all expressions, while females were considered to be left-biased for negative emotions only. A sex by valence interaction has been reported by Borod in several studies of posed and spontaneous emotional facial expressions (Borod and Caron, 1980; Borod et al., 1983; Borod et al., 1990).

There have been other studies that have reported a left-sided bias during involuntary emotional expressions. For example, both Moscovitch and Olds (1982) and Dopson et al. (1984) instructed subjects to describe emotional experiences and had judges rate their expressivity. Moscovitch and Olds (1982) videotaped the expressions and asked judges to rate the quantity of expressive movements for each hemiface, while Dopson et al. (1984) photographed subjects, created hemiface composites, and then had judges rate the quality of the expressions on a seven point likert scale. Both studies suggested a left hemiface bias for expressivity. In a similar manner, Wylie and Goodale (1988) reported a left-sided asymmetry for spontaneous emotional expressions. In their study, they utilized digitized image analysis to measures changes in the spatial position of

facial markers. The distance the facial markers moved during an expression was considered the dependent variable.

Not all research, however, has found a left hemiface bias. For instance, Hager and Ekman (1985) employing FACS, a system which rates individual muscle movements, found that spontaneous smiles and startle reactions were symmetrical. In addition, Rothbart, Taylor and Tucker (1988) examined the whole face of infants during emotional expressions. They reported that the still images from videotapes displayed a right-sided, rather than left-sided bias. Furthermore, several studies have suggested that the left hemiface is more expressive for negative emotions and the right hemiface is at least as intense as the left hemiface for positive emotions (Schwartz et al., 1979; Sirota and Schwartz, 1982; Borod et al., 1983; Hartley, Coxon and Spencer, 1987).

In sum, the research on spontaneous expressions indicates that expressive asymmetries generally exist, although the direction of the bias may depend upon the valence of the emotion. Due to the bilateral pattern of innervation associated with involuntary expressions (Thompson, 1985; Pizzamiglio et al., 1989), it is unclear whether these results are indicative of a hemispheric specialization for emotional production. Because expressivity is assessed across the entire face for studies of brain damaged subjects, an investigation of spontaneous expressions in these patients might be more relevant for

testing the RH and Valence hypotheses. Consequently, the problem of bilateral innervation becomes irrelevant.

Spontaneous Expressions in Brain-Impaired Subjects

As with the study of spontaneous expressions in normals, research with brain-impaired patients is generally, but not conclusively, consistent with the RH hypothesis. For example, Buck and Duffy (1980) instructed eight untrained raters to examine a videotape of subjects' responses to affectively-laden slides. They reported that in comparison with LBDs and NCs, RBDs were less accurate and less expressive. Several studies by Borod and colleagues also indicate that subjects with right brain disease are impaired in either their appropriateness (consistency with emotional character of elicitor stimulus), intensity (muscle movement) or responsivity (occurrence of an expression) of their emotional facial expressions (Borod, Koff, Lorch and Nicholas, 1985; Borod et al., 1988; Martin et al., 1990). Furthermore, in a study of RBDs, LBDs and NCs, Blonder et al. (1993) reported RBD impairment for the expression of positive, but not negative emotion. They measured expressivity during natural conversation using a seven point anchored (with emotional facial referents) likert scale.

Not all studies, however, have concluded that RBDs are less impaired in their expressivity than LBDs. For example, Mammucari et al. (1988) employed FACS as well as subjective ratings of emotional expressivity and found that emotionally

evocative films elicited similar levels of expressivity for RBDs and LBDs. On the other hand, a study by Weddell, Trevarthen and Miller (1988) which also utilized both subjective raters and FACS found a dissociation between the measures. In their study of RBDs and LBDs, subjective raters indicated that RBDs displayed less intense negative expressions to a frustrating card-sorting task, yet the groups did not differ from one another based on FACS. In both the Weddell et al. (1988) and the Mammucari et al. (1988) studies, impressionistic ratings of whole face dynamic images were employed.

Taken together, research on the spontaneous expressions of brain-impaired subjects does not provide clear support for the RH hypothesis. It is noteworthy that most of the research consistent with the RH hypothesis has been conducted by Borod and colleagues, while the negative findings have occurred in other laboratories. Furthermore, the results of the Blonder et al. (1993) study which appear to support the RH hypothesis are also consistent with the view that the lower expressivity of RHD subjects are caused by an arousal deficit (Heilman and Watson, 1989; Heilman, Bowers and Valenstein, 1993). Consequently, the question remains debatable as to whether a hemispheric specialization for emotion is the source of lowered expressivity among brain-impaired subjects.

<u>Posed Expressions in Brain-Impaired Subjects</u>

Posed emotional expressions by brain-impaired subjects has been generally, but not conclusively, consistent with the RH hypothesis. For example, Borod and colleagues have presented several studies which suggest that RBDs are less accurate and less expressive in their production of emotional faces as compared to LBDs and NCs (Borod et al., 1986, Borod, St, Clair et al., 1990, Borod, Welkowitz et al., 1990). In one of the more recent articles, trained judges examined the facial asymmetry of subjects posing angry and happy expressions (Borod, St. Clair et al., 1990). Using both whole images and mirror reversals, they found that there was a smaller level of asymmetry for RBD subjects. Because less expressivity would be associated with less asymmetry due to the contrast between the paretic and nonparetic sides of the face, they concluded that the right hemisphere was intimately involved in the production of emotion. In another study, Richardson et al. (1992) instructed judges to view dynamic whole images of LBDs, RBDs and NCs posing facial expressions. They rated the accuracy of five facial expressions across a variety of elicitation procedures and found that RBDs were particularly impaired when nonverbal means were used to elicit the posed expression. Weddell et al. (1990) employed FACS and impressionistic ratings in their study. Post hoc analyses suggested an expressive deficit for RBDs. Subjective

ratings of dynamically presented whole faces indicated that the appropriateness of their expressions were not significantly different. Unlike nearly all other research, the lesions in the Weddell et al (1990) study were tumoral, rather than stroke-related.

Although the above studies suggest a right hemisphere advantage for the production of emotional behavior, other research has not been supportive of the RH hypothesis. For example, Heilman, Watson and Bowers (1983) examined five RBD patients and five LBD patients and did not find any differences in their ability to pose facial expressions upon command. Furthermore, Caltagirone et al. (1989) used both FACS and subjective ratings of dynamically presented whole faces, and regardless of the measurement system employed, did not find any group differences between RBDs, LBDs and NCs. Finally, Kolb and Taylor (1990) reported a collection of their studies in which hemispheric differences were either mild, nonexistent or less compelling than frontal vs. parietal differences. Thus, the evidence has been mixed in its support of the RH hypothesis.

Posed Expressions in Normals

The final approach utilizing the facial channel involves the comparison of expressive asymmetries by normals during posed emotional expressions. Because the lower face is contralaterally innervated for voluntary expressions (Crosby and Dejong, 1963; Kahn, 1964; Rinn, 1984),

inferences about hemispheric involvement can be made more readily. Consistent with other research suggesting a RH involvement, the majority of these studies indicate that asymmetries favor the left side of the face which is predicted by the RH hypothesis. A summary of studies on posed expressions by normals is located in the appendix.

The first major study examining facial asymmetries during posed emotional expressions was conducted by Sackeim et al. (1978). They presented a series of composite slides (a whole face constructed of one hemiface and its mirror image) to 86 students and instructed them to rate the intensity of the emotional expression. The results indicated that the composite slides from the left side of the face were more intense. They considered the left-sided bias in their study to be the consequence of a right hemisphere advantage in processing emotional material. In the same year, Campbell (1978) published a study in which left-sided composite slides of smiles were rated as happier and left-sided composite slides of neutral expressions were rated as sadder. A follow-up study with left-handers as subjects found the same pattern for smiles only. For the neutral expression, the opposite results were reported such that the right composites were rated as being sadder (Campbell, 1979).

A set of studies published by Borod and colleagues in the early 1980s were generally consistent with the findings

of Sackeim et al. (1978), although they reported some evidence of sex differences interacting with the emotional valence of the expressions. For example, in their first paper, Borod and Caron (1980) indicated that males displayed a significantly greater left bias than females for negative emotions. In their procedure they produced videotaped stills of the peak expressions and had three raters estimate the degree of asymmetry on a 15 point scale (-7 to +7, left vs. right bias). In a follow-up study, Borod et al. (1981) reported that the intensity of the facial expressions were also left-biased. In 1983, Borod and colleagues published two studies which generally indicated that there was an asymmetrical bias toward the left side of the face and that morphological features appeared unrelated to the bias (Borod and Koff, 1983; Borod et al., 1983). Both of the studies relied on a dynamic presentation as well as multiple emotions representing both a positive and negative valence. In one of the studies, only males showed a left-sided bias for positive emotional expressions (Borod et al., 1983).

In addition to the Borod group, other researchers were finding results generally consistent with Sackeim et al. (1978). For example, Rubin and Rubin (1980), Heller and Levy (1981) and Dopson et al. (1984) all reported a left-sided bias for posed smiles. In the former study, the left-sided composite photographs of children were more often chosen (forced choice) as more intense for both negative and

positive emotional expressions. In the second study, hemiface chimeric photographs were assembled from happy and neutral expressions of the same hemiface so as to account for any hemiface differences at rest. Only a positive expression was examined and the results indicated a left-sided bias. Finally, in the latter study, composite photographs of sad expressions were investigated as well as smiles with similar results. All of the above studies relied on at least two dozen untrained raters to determine the degree of emotional expressivity or intensity.

During this time, however, two separate laboratories conducted research using different methodologies and generally failed to uncover significant facial asymmetries. For example, Schwartz and his colleagues published two studies in which they measured EMG at the corrugator and zygomatic muscle sites during voluntary emotional facial production (happy and sad) and found very little evidence of significant differences between the hemifaces (Schwartz et al., 1979; Sirota and Schwartz, 1982). In addition, Ekman's group reported results from two studies which were more favorable to the RH theory, yet generally unsupportive of it (Ekman, Hager and Friesen, 1981; Hager and Ekman, 1985). In the former study, children initiated facial movements suggestive of an emotion. Approximately one-fifth of the subjects displayed a left-sided bias. In the latter study with adults, the overall effect along with most of the

individual muscle sites were rated as symmetrical.
Nevertheless, one muscle pair (zygomatic) which is involved
in smiling did display a left-sided bias.

Following these investigations, Borod and her
colleagues reported further evidence of left-sided asymmetry
in two studies in which male and female posers were studied
separately (Borod et al., 1988; Moreno et al., 1990). For
both experiments, multiple positive and negative emotions
were posed. In the study with female subjects, composite
photographs of women of varying ages were rated on a seven
point intensity scale. Evidence of greater asymmetry on the
left side of the face was found across all age groups
(Moreno et al., 1990). In the study of male posers, left
and right hemiface video stills were presented in normal and
mirror images. The poses were elicited through command and
mimicry. Once again, a left-sided bias was found (Borod et
al., 1988).

In contrast to these two studies, Wylie and Goodale
(1988) reported no significant differences in hemiface
activity during posed smiles. Their technique for assessing
facial activity relied on the digitized analysis of changes
in spatial positioning of facial markers. Once again, an
"objective" approach failed to find clear evidence of
expressive asymmetries in normals.

Before discussing possible methodological issues, two
additional studies that investigated expressive asymmetries

of brain diseased subjects and normal controls are deserving of mention. The first study was noteworthy in that it employed both a subjective rating system and a more objective or less impressionistic method. It was conducted by Caltagirone et al. (1989) who examined the hemifaces of brain impaired subjects and normal controls using both subjective ratings and FACS. Neither FACS nor the subjective ratings, however, revealed any evidence of a left-sided advantage for normals. In addition, both LBDs and RBDs displayed a small hemiface bias ipsilateral to their lesion. This bias was expected given a likely hemiface paresis contralateral to their lesions, and indeed, facial action scores were significantly correlated with the degree of contralateral hemiface paresis.

In the following year, however, Borod, St. Clair et al. (1990) conducted comparable research using only subjective raters. Similar to the prior study, subjects produced expressions on command while being videotaped. Trained raters then examined still images and their mirror reversals and judged the degree of asymmetry of each on a -7 to + 7 left-right scale. Consistent with her previous work, normal controls were rated as having a left-sided asymmetry. In addition, LBDs were also determined to have a left-sided asymmetry which was hypothesized to be primarily related to a right hemiface paresis. For RBDs, however, no significant asymmetries were found. Borod, St. Clair et al. (1990)

concluded that the left hemiface paresis of RBDs was compensated for by a left-sided bias produced by the remnants of the emotional production center contained in the right hemisphere - a view consistent with the RH hypothesis.

Morphological Variation

Proponents of the RH hypothesis have argued that left-sided asymmetries during emotional expressions are the consequence of greater RH specialization for emotional production. Others have suggested that morphological explanations provide a more parsimonious interpretation of expressive asymmetries. Indeed, following the assertion by Sackeim et al. (1978) that emotions are more intensely expressed on the left side of the face, critics have argued that basic morphological factors (e.g. differences in the size and structure of the hemifaces) are the likely determinants of a lateral bias (Ekman, 1980; Nelson and Horowitz, 1980). Nelson and Horowitz (1980) measured the widths of the left and right sides of the face and reported that the right side of the face was smaller than left. They believed that the left side appeared more expressive than the right because the facial movement involved a greater percentage of the left hemiface. Ekman (1980) asserted that, in general, one side of the face contains a greater percentage of fatty deposits or soft tissue matter and that such a difference may have influenced the subjective ratings.

If morphological asymmetries influence one's impression of expressive intensity, the same bias may also affect one's perception of a resting face. It is conceivable that a neutral face is the absence of an emotional expression, and therefore, perceived emotional asymmetries on a resting face are the result of morphological asymmetries, rather than a hemispheric specialization of emotion. Campbell (1978) reported that the resting left hemiface of normals is perceived to be more expressive (sad) than the right. Additionally, Schwartz et al. (1979) found that the left hemiface displayed greater EMG ratings at rest than did the right, although it was unclear whether the EMG ratings were the result of soft tissue differences or unintended anxiety caused by the laboratory setting. In contrast, Hager and Ekman (1985) did not find any facial asymmetries at rest when FACS was employed.

As Schwartz et al. (1979) reported, it is debatable that a neutral expression is nonemotional. A morphological explanation may account for perceived emotional asymmetries during neutral expressions, yet there are alternative interpretations that are consistent with the RH hypothesis. First, the production of a neutral expression may reflect an internal emotional state which requires the involvement of the same process associated with the production of other emotional states. If a RH emotional production system were utilized to initiate a neutral expression, then a left

hemiface asymmetry for a neutral expression would be consistent with the RH hypothesis. Second, as Schwartz et al. (1979) recognized, subjects are not an empty vacuum of emotions during an experiment. They may be anxious about their performance, or the nature of the study, and subtle emotional expressions may seep into their purportedly neutral countenance.

Given the argument that a neutral expression may, in fact, be emotional, a more direct measure of morphological asymmetries is necessary to address this question. Consequently, several authors have reported information on the facial structure of their subjects. Sackeim and Gur (1980), Borod et al. (1983) and Sackeim, Weiman and Forman (1984) examined whether morphological biases were creating the impression of expressive asymmetries. They concluded that the facial structure of their subjects was generally symmetrical. Furthermore, Sackeim (1985) conducted a comprehensive review of the literature on facial structure which indicated that the face was remarkably symmetrical.

Sackeim's (1985) review of facial structure included studies which measured both hard and soft tissue factors. The soft tissue that was most likely accounted for in these studies was that of muscle and fat. Other soft tissue factors may influence facial expressivity. Perhaps, patterns of facial innervation may be involved in expressive asymmetries. For example, pure muscle strength may not be

as important as one's adeptness in performing discrete muscle movements. Crisp and precise facial movements may be responsible for perceived facial expressivity. Asymmetries in neural involvement might explain a hemiface superiority in movement precision. In that case, the role of the peripheral nervous system would be critical and may be the source of expressive asymmetries (Thompson, 1985; Borod and Koff, 1990).

Regardless of which factor is most crucial (e.g. muscle mass, differences in innervation or other structures) Borod and Koff (1983) examined the general question of facial mobility. They instructed subjects to make nonemotional, unilateral facial movements centered around the mouth and eyes. Raters compared which side of the face displayed superior movement and the left side was rated as significantly more mobile. The Borod and Koff (1983) study suggests that the left side of the face is more facile than the right in producing nonemotional as well as emotional expressions. Consequently, asymmetries for emotional facial expressions may be secondary to biases in hemiface mobility.

Borod and Koff (1990), however, argued that a left hemiface advantage for nonemotional expressions does not, in itself, negate the possibility of a hemispheric influence on emotional expressions. It may be that the two systems are relatively unrelated to one another. In the same manner that there exists a partial dissociation between the spatial

processing and emotional face processing capabilities of the right hemisphere (Bowers et al., 1985), so too, may emotional and nonemotional expressivity be partially disassociated. Borod and Koff (1983) examined this very question and found that a left-sided bias in mobility was generally unrelated to a left-sided bias in emotional expressivity. The statistical methodology in the Borod and Koff (1983) study has received criticism. For instance, Campbell (1986) voiced concern about the stringency of their test of association which might be susceptible to a type II statistical error. Consequently, Campbell (1986) argued that a left-sided bias in mobility may be responsible for the lateral bias in emotional expressions.

Given the research published thus far, it appears that morphological factors (particularly in regards to facial mobility) cannot be dismissed as a possible explanation of facedness during emotional expressions. On the other hand, there has been a dearth of evidence linking expressive asymmetries with morphological factors. As a result, the design of this study will attempt to test for advantages in facial mobility, the most promising morphologically related factor.

Methodological Differences

To date, the neuropsychological literature on asymmetries of voluntary emotional expression for normals remains inconclusive, although the majority of studies do

favor a left-sided bias for emotional expressions. A variety of methodological factors exist which may have contributed to the contradictory results. Clearly, no identifiable one completely accounts for the conflicting data. Factors suggested by Borod and Koff (1990) in their review of the literature include the following: (a) method of elicitation (command, imitation, imagery), (b) gender, (c) process for capturing expression (dynamic vs. static), (d) subject awareness of camera (naive, alerted but unseen, completely aware), (e) method of presentation of faces (composites, mirror reversals, hemifaces, normal images), (f) method of analysis (subjective impressions, FACS, EMG, mathematical analysis of movement), (g) dimension of rating scale (intensity, asymmetry, appropriateness, expressivity) as well as (h) the number and valence of emotions posed. A summary of the research on posed expressions by normals is located in the appendix.

The first factor to be considered is the method of elicitation. There are a variety of techniques employed to evoke a target emotion. The most commonly used approach is the direct "verbal request" or command (e.g., show me a sad face). Because nearly every study has utilized the command procedure, it seems unlikely that this variable explains the discrepant results within the literature. When other approaches have been utilized to elicit the desired expression, they have generally been used in conjunction

with direct commands (Borod et al, 1983, 1988; Wylie and Goodale, 1988). The other approaches include facial imitation, verbal scenarios and scenic photographs. In these conditions, subjects are expected to express emotions that are consistent with verbally presented scenarios or emotionally laden pictures. Borod et al. (1981) conducted the only study which did not employ direct commands and their findings suggested a general left-sided bias. Given that no other study refrained from employing direct commands, it is unclear whether expressive biases are more likely when a poser must determine the target emotion by interpreting nonverbal stimuli.

Based on research with focal lesion patients, there is evidence that expressive deficits may be affected by the method of elicitation. For example, Richardson et al. (1992) found that impairments in voluntary facial expressivity were secondary to deficiencies in the evaluation of nonverbal stimuli. In their study, RHDs were no different than LHDs or NCs in their ability to produce accurate emotional expressions when a stimulus was presented verbally, but were more likely to display expressive deficits for a stimulus presented nonverbally. Based on these results, expressive asymmetries with normals may be the consequence of hemispheric advantages in processing affective information. Perhaps, nonverbal stimuli more strongly engages the right hemisphere which enhances the

likelihood of a left-sided expressive asymmetry. Although this question deserves further inquiry, the fact that expressive biases have generally been found under command conditions suggests that it does not explain the discordant results of prior research.

Another manner in which the research has varied is in the number and valence of the emotions posed. For number, there exists no discernible pattern which indicates that this factor explains previous discrepancies. The valence of the target emotions also appears inadequate as an explanation. For example, some studies have failed to find an expressive bias for the happy expression (Schwartz et al., 1979; Sirota and Schwartz, 1982; Wylie and Goodale, 1988), but most research has been associated with left facedness for positive expressions (Campbell, 1978, 1979; Heller and Levy, 1981; Borod and Koff, 1983; Braun, Baribeau, Ethier, Guerette and Proulx, 1988; Moreno et al., 1990). Furthermore, nearly all of the studies that failed to find expressive asymmetries included positive and negative emotions, thus suggesting valence was not the fundamental issue (Sirota and Schwartz, 1982; Hager and Ekman, 1985).

For research relying upon subjective raters, an additional variation has been the nature and dimension of the rating scales. In regards to dimension, judges have been asked to rate the levels of asymmetry (Borod and Koff,

1983), intensity (Sackeim et al., 1978; Borod et al., 1981), expressivity (Dopson et al., 1984) and emotionality (Cacioppo and Petty, 1981) of facial expressions. Concerning the nature of the scale, raters have used both likert-type scales (Sackeim et al., 1978; Borod and Caron, 1980; Dopson et al., 1984) and forced choice procedures (Campbell, 1978, 1979; Heller and Levy, 1981; Braun et al., 1988) in making their judgments of hemiface differences. Regardless of the scale, the results have nearly always been associated with left facedness. Thus, it appears that the type of scale is unrelated to the discrepant findings within the literature.

Another way in which the research has differed is in the method of capturing and presenting facial expressions. Some studies have relied on static means, such as still photography (Dopson et al., 1984; Braun et al., 1988), while others have utilized more dynamic methods, such as videotaping (Borod et al., 1981; Borod and Koff, 1983; Hager and Ekman, 1985). A combined approach has been to videotape facial expressions and present to the raters, a one frame video still (Borod and Caron, 1980). For research relying upon subjective ratings, dynamic vs. still images appears unrelated to any discrepancies within the research. Expressive asymmetries have been found with both approaches. The one study in which subjective raters failed to find a lateral bias utilized a dynamic method for both the capture

and the presentation of the emotional expressions (Caltagirone et al., 1989). In general, however, the dynamic presentation of facial expressions has been associated with expressive asymmetries (Borod et al., 1981; Borod and Koff, 1983; Borod et al., 1983). Therefore, the method of capturing and presenting the emotional stimuli does not explain the discordant results of prior research.

Another factor that differed between studies is the strategy employed for the presentation of the target emotions. For example, judges have been instructed to make ratings of pictures with normal images (real life photographs or videotaped images), mirror reversed images (reversal of hemiface position such that left side appears on right and vice versa), hemiface composites (whole face constructed of a hemiface and its mirror reversal) and hemifaces alone (only one-half of the face). Each of these methods has its advantages and disadvantages. Nevertheless, there have been no systematic differences associated with any of the different presentation procedures.

One methodological factor which may explain some of the prior discrepancies is that of camera obtrusiveness. In two of the studies not supporting the RH hypothesis (Hager and Ekman, 1985; Caltagirone et al., 1989), subjects were either unaware of being videotaped or the camera was nearly hidden from view. For most other research, the camera has been placed in plain view of the subject. It is possible that

the subjects altered their expressions because of the demand factors associated with being videotaped. Perhaps, videotaping elicits an inhibitory response in subjects, and thus, asymmetrical differences appear as a result of the right hemiface being more inhibited than the left.

The role of inhibitory factors in the production of emotional facial asymmetries has been debated. Rinn (1984) argued that the left hemisphere may have an advantage in the inhibition of emotion. He reasoned that because of the cognitive complexity of verbal processing, the left hemisphere has an advantage in modulating affect. A left hemisphere advantage for inhibiting emotion should result in greater control of the right hemiface, and consequently, an appearance of greater left hemiface expressivity. This effect is predicted to be more salient under conditions in which the desire to inhibit an emotional expression is enhanced. Because social demand factors may be greater during videotaping, Rinn's (1984) inhibitory hypothesis would predict greater left-sided asymmetries. Conversely, when the photographs or videotaping occurs without the subjects' knowledge, lateral biases should be less likely. Consistent with Rinn's (1984) inhibitory hypothesis, there was a lack of emotional facial asymmetries found by Hager and Ekman (1985) and Caltagirone et al. (1989) when either an unobtrusive or hidden camera was employed. Further research is needed to explore this possibility.

Gender is the next factor which may be associated with the presence of an emotional facial asymmetry. When facial asymmetry research is divided by gender, asymmetries are more often associated with male subjects, than female subjects. For example, two of the three studies which included only female subjects failed to find substantial evidence of facedness during emotional expressions (Hager and Ekman, 1985; Sirota and Schwartz, 1982). In addition, Borod et al. (1983) found no evidence of lateral biases for females posing positive emotions; although, negative expressions were asymmetrical. Most notably, all three male only studies were associated with a significant lateral bias.

The finding that males are more likely to display expressive asymmetries is consistent with neurological evidence that the male cortex may be more lateralized and that the female cortex may have greater interhemispheric connectivity (McGlone, 1980). Both the enhanced laterality of the male cortex and the greater interhemispheric connectivity of the female cortex may contribute to greater expressive asymmetries for males. Consequently, research including a large percentage of female subjects may be less likely to find expressive asymmetries.

The final factor, method of analysis, appears to be an important source for much of the discrepancies in prior research. The methods of analysis are generally divided

into studies emphasizing subjective vs. "objective" techniques. Nearly all studies supportive of a left-sided asymmetry have relied on subjective, holistic impressions, whereas most of the studies which have failed to find substantial asymmetries have utilized more objective procedures. Critics of the subjective methods have argued that impressionistic ratings are less reliable and more vulnerable to possible errors (Hager and Ekman, 1985). Indeed, it has been suggested that apparent asymmetries in emotional production may be the result of a perceiver bias, whereby symmetrical expressions appear asymmetrical because human raters have a perceptual advantage for the left visual field (Borod and Koff, 1990). Research indicates that a perceiver bias does exist and it directly contributes to the perception of facial asymmetries (Gilbert and Balkan, 1973; Bennett et al., 1987).

On the other hand, perceptual biases have been controlled for in most investigations. In some experiments, removing the bias has been accomplished by presenting each test face and its mirror image to the raters (Borod et al., 1988; Moreno et al., 1990). In other studies, hemiface composites have been used such that the mirror image of each hemiface is attached to its original (Sackeim et al., 1978; Dopson et al., 1984; Braun et al, 1988). In this way, a left-left composite may be compared to a right-right composite. In addition, research reporting a perceiver bias

have consistently found a left visual field (LVF) advantage
such that the right hemiface (falling in the perceiver's
LVF) is preferred. A right hemiface bias works against the
hypothesized direction of left facedness, and therefore,
reduces the likelihood of a positive finding. Thus, it
seems unlikely that a LVF bias could create the illusion of
a left-sided expressive asymmetry.

Composite images and mirror reversals may control for
visual field advantages of the raters, however, it cannot
eliminate the effect of structural asymmetries within the
posers. It is conceivable that biases are elicited by
certain facial features such as bone size and muscle mass.
Such hemiface differences may affect subjective ratings. No
evidence, however, has been found that purported structural
differences are associated with emotional asymmetries (Borod
and Koff, 1990; Sackeim, 1985).

To date, nearly all research which has found
asymmetries in emotional facial expressivity has relied on
the holistic impressions of subjective raters. In contrast,
nearly all of the studies utilizing more "objective" means
have failed to find the association. For example, studies
employing EMG as a measure have generally not supported a
left hemiface bias in expressivity (Schwartz et al., 1979;
Sirota & Schwartz, 1982). Furthermore, no significant
asymmetries were reported using a digitized analysis of
movement of facial markers, although a weak right-sided bias

was found for right-handers only (Wylie and Goodale, 1988).
Finally, those who have employed FACS have generally failed
to find any substantial left-sided bias among normals
(Caltagirone et al. 1989; Hager and Ekman, 1985).

While subjective rating systems may be susceptible to
perceptual error, the more objective measures may have
lacked sensitivity. Perhaps, human raters have a greater
appreciation of the facial gestalt which may be missed by
the objective, more reductionistic techniques (Buck, 1990;
Blonder et al., 1993). For example, Ekman et al. (1981)
reported that only one quarter of the subjects had
asymmetrical smiles, mostly favoring the left hemiface. In
a subsequent study, Hager and Ekman (1985) found a left-
sided asymmetry for the zygomatic muscle during smiles.
Since the zygomatic muscle is quite powerful in altering the
contours of the emotive face, it is not surprising that this
area would be the one action unit where FACS detected an
effect, especially if the technique lacked sensitivity.

As for the two EMG studies, the generally negative
findings may be related to several possibilities. First,
only two of the facial muscle groups were monitored such
that a complete and accurate portrayal of all muscle
activity throughout each hemiface was not available. In
addition, surface EMG, rather than a more invasive EMG
technique was used which decreases the accuracy of the
measurement and increases the error variance. Finally, the

mere presence of the electrodes may have altered the facial expressions of the subjects. Thus, it remains debatable as to whether EMG is an effective measurement device for assessing emotional facial asymmetry.

The last "objective" method employed was that of digital image analysis in which changes in spatial positioning of several facial markers were calculated. Wylie and Goodale (1988) marked several points on the left and right side of a subject's lips along with one mark on each cheek and another on the nose. They examined smiles in both spontaneous and posed conditions and reported that there were significant asymmetries only in the spontaneous condition. Because changes in just a few facial points were measured, one might question the sensitivity of this technique. On the other hand, the fact that positive results were found in the spontaneous condition suggests that the method appears to be sensitive enough. Other factors, however, may have been associated with the discrepancy between this method and the impressionistic approaches. For example, the lighting during the experiment was so bright that dark sunglasses were required. Perhaps, the discomfort from the bright lighting inhibited facial expressivity. In addition, wearing dark sunglasses may have seemed unnatural and interfered with normally posed expressions. Finally, an interaction effect between the procedure and a borderline level of sensitivity may have

reduced the likelihood of finding emotional facial asymmetries.

Taken together, peculiar characteristics of each of the "objective" methods may have reduced their sensitivity. Of the three approaches, the digitized image analysis holds the greatest promise as a powerful, nonintrusive measure. By employing an alternative strategy with the digitized image analysis, sensitivity can be increased and artificiality can be decreased. Instead of examining changes in spatial positioning, it is proposed that measuring changes in greyness across the face is a more powerful approach since more of the face is taken into account. Furthermore, the lighting required for this approach would not have to be so intensely bright. Consequently, any artificiality produced by wearing sunglasses would be avoided. For these reasons, we have introduced the digitized approach for the assessment of expressive asymmetries.

Evidence supporting the efficacy of this technique was found in a study conducted by Leonard, Voeller and Kuldau (1991) who employed both digital image analysis and subjective ratings of smiles. Although facial asymmetries were not the focus of their study, they did find strong agreement between the output of the digital and subjective approaches. Their results indicated that digitized image analysis may be sensitive enough to capture signals that

impressionistic raters perceive, but other more objective measures appear to miss.

In a pilot study conducted in our laboratory, further evidence was found supporting the utility of digitized image analysis (Richardson, Bowers, Leonard and Heilman, 1994). In the study, dynamic emotional facial expressions were obtained from 20 self-reported right-handed subjects. Five different emotions were videotaped and digitized using the Xybion Image Capture Analysis System (XICAS). Change in pixel intensities between adjacent video frames was calculated by subtracting the level of greyness at each pixel location. Level of greyness is a numerical representation from 0 to 256 of the brightness of each pixel on the video monitor. A mean difference score from two adjacent video frames was computed by summing all the difference scores from each pixel location and dividing by the total number of pixels utilized. Because 13 frames were analyzed for each expression, 12 mean difference scores were summed together to produce a grand total difference score which reflected the overall change in pixel intensities over a 400 msec period.

The grand total difference score for the greyness level represented a quantified measure of movement and was calculated for each hemiface across all subjects in the pilot study. More movement as indicated by the grand total difference score was detected on the left side of the face

for males while posing angry and frightened faces. A left-sided trend was also found for males posing sad expressions. No significant differences were found in the happy and disgust condition. Nor were any significant differences or trends found for females in any of the conditions. Thus, the results of the pilot study (10 males and 10 females) suggested that digitized image analysis has the sensitivity to detect facial asymmetries. A larger number of subjects, however, is required to determine the robustness of these findings.

GENERAL ISSUES ADDRESSED

Several questions were addressed in this study:

1)   The first question of interest asked whether emotional expressions are asymmetrical and whether the valence of the emotional expression impacts the direction of the asymmetry. Previous research has been somewhat supportive of an asymmetrical bias during voluntary emotional expressions. The two most commonly cited hypotheses in the neuropsychological literature are referred to as the Right Hemisphere (RH) hypothesis and the Valence hypothesis. The former proposes that regardless of emotional valence, emotional processing and production is primarily a right hemisphere function. Consequently, a left-sided asymmetry for voluntary emotional expressions would be consistent with the RH hypothesis due to the contralateral innervation of the lower face (Rinn, 1984; Thompson, 1985). The alternative perspective is the Valence hypothesis, and it proposes that the right hemisphere is specialized for the processing of negative emotions, while the left hemisphere is involved in the processing of positive emotions. Some researchers have conceptualized the dichotomy of the Valence hypothesis in terms of approach and withdrawal, rather than positive and negative valence (Davidson, 1993).

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In general, the research on emotional production is more consistent with the RH hypothesis than the Valence hypothesis, although there are several studies which have failed to support either perspective. In order to test these two hypotheses, subjects were asked to pose both a positive and negative facial expression. Both digitized analysis and impressionistic judgments were employed to determine whether emotional valence interacts with the direction of a hemiface asymmetry.

2)   The second question of interest was whether the pattern of expressive asymmetry is consistent with our current knowledge of facial innervation. In other words, which portion of the face (upper vs. lower) was a lateral bias more likely. Neuroanatomical research indicates the lower and upper portions of the face have a different pattern of innervation. Rinn (1984) reported that there is a significant amount of both ipsilateral and contralateral innervation from the brow region of the face down to the upper eyelids. Below this point, the face is thought to receive primarily contralateral innervation. If expressive asymmetries are primarily the result of a hemispheric specialization, then the lower portion of the face should display the greatest asymmetry. Results indicating either no difference in the degree of asymmetry or greater upper face asymmetry would suggest that other processes were at work. Morphological factors such as hard or soft tissue

differences have been proposed as alternative sources of expressive asymmetries (Ekman, 1980; Nelson and Horowitz, 1980). They propose that expressive asymmetries are a perceptual phenomena caused by differences in fatty deposits or bone structure in the posers.

Although structural factors appear to be a credible explanation for expressive asymmetries, there is little evidence supporting this position. In a review of the anatomical literature, Sackeim (1985) concluded that the face was remarkably symmetrical. Furthermore, he and his colleagues did not find a correlation between hemiface size and ratings of emotional expressivity (Sackeim et al., 1980). Thus, neuropsychological mechanisms appear to be more capable of accounting for expressive asymmetries than structural biases. On the other hand, if neuropsychological hypotheses are correct, then the pattern of expressive asymmetry should be consistent with our current knowledge of neuroanatomy. Therefore, the degree of emotional asymmetry in the upper or lower portions of the face was assessed utilizing digitized image analysis.

3) The third question of interest asked whether another morphological characteristic (facial mobility) is correlated with emotional facial asymmetries. Perhaps, the underlying mechanism for the laterality of emotional expressions is a general asymmetry in facial agility. Accordingly, all

expressions, regardless of emotionality may display a lateral bias.

There is some evidence consistent with an asymmetry in facial mobility. Chaurasia and Goswami (1975) and Borod et al. (1983) reported a left-sided bias for nonemotional expressions. Borod et al. (1983) indicated, however, that the left-sided advantage for mobility was uncorrelated with emotional facial asymmetry. Given that Borod et al. (1983) found a difference in hemiface mobility, the degree of hemiface activity during nonemotional facial expressions will be assessed. Likewise, the level of correlation between emotional and nonemotional facial activity was calculated to determine whether hemiface mobility is associated with emotional facial asymmetry.

4)   The fourth question of interest asked to what degree does the digitized image analysis correspond to impressionistic ratings. Previous research has failed to find a correlation between impressionistic ratings and more objective measures of expressive asymmetry. It has been suggested that the objective methods previously employed may have lacked the sensitivity required to detect what subjective raters perceive (Blonder et al., 1993). A digitized approach may be capable of such sensitivity.

Nonetheless, results from the impressionistic portion of the pilot study did not indicate a significant level of agreement between the digitized image analysis and the

subjective ratings (Richardson et al., 1994). In the pilot study, three untrained raters were presented a left-left and right-right composite image for each posed emotion and were asked to select the more intense expression. Results for male subjects indicated that the left composites were rated as more intense for disgust, while a trend favoring the right composites were found for sadness. For females, a left-sided bias was found only for the happy condition. The discrepancy between the subjective results and the digitized analysis was striking. Indeed, a direct comparison between the two for each individual face indicated that the agreement was at chance levels.

There were, however, several methodological weaknesses in the pilot study that likely affected both the digitized data and the subjective ratings. First, the control of head movement was not completely secured. Because movement alters the level of greyness at each pixel, any concurrent head movement would likely distort the pixel intensities and possibly provide inaccurate information regarding facial emotional intensity. Second, the brightness of the lighting was not specifically measured at each hemiface, thus leaving open the possibility of a lighting bias which may have falsely created an asymmetrical bias. Third, because some studies have found that males tend to be more asymmetrical in the production of emotional facial expressions, a significant hemiface advantage in expressivity may have been

limited by the small number of males (10) included in the pilot study. Finally, subjective raters were untrained and intrarater reliability was not measured. There may have been a substantial degree of variability within the raters' judgments.

Despite weaknesses in the pilot study, it did demonstrate that digitized imaging is an effective tool for the measurement of expressive asymmetries. In addition, it is the first "objective" method to validate the consistent findings of the impressionistic approaches. Although the correlation between the digitized analysis and the subjective ratings in the pilot study suggested no relationship between the two methods, it is likely that methodological issues are responsible for the dissociation. Subjective ratings from nearly all prior studies of voluntary emotional production have found a left-sided bias. Given the unusual findings from the subjective raters in the pilot study, impressionistic ratings were also obtained and compared to the results of the digitized image analysis.

5) The fifth question of interest was from what portion of the face (upper vs. lower) do subjective raters primarily base their judgments of emotional facial asymmetry. Neuroanatomical evidence has suggested that the lower portion of the face receives more contralateral innervation than the upper portion. The upper region is thought to receive predominantly bilateral innervation (Rinn, 1984).

Consequently, greater emotional asymmetry in the lower portion of the face is consistent with the emotion based hypotheses. Using the digitized image analysis, the degree of asymmetrical motion for each portion of the face can be determined. The digitized image analysis is based on a dynamic measure of expressivity and the subjective ratings are made from static images. Nonetheless, one would expect that the greater the asymmetry in dynamic movement, the more the static image should reflect that bias. A comparison between the digitized analysis for the lower and upper portions of the face and the subjective ratings of the whole face was taken to determine which portion of the face has a greater influence on the impressionistic ratings.

6)   Finally, the sixth question of interest explored to what degree does training raters increase the likelihood of reliable and consistent findings. For the studies of emotional facial asymmetry that have employed subjective ratings, often, only three raters were used to assess expressivity (Borod et al., 1981; Borod and Koff, 1983; Borod et al., 1988; Moreno et al., 1990). Generally the raters were trained in rating emotional expressions. Other studies have relied upon many untrained raters (Sackeim et al., 1978; Heller and Levy, 1981; Dopson et al., 1984; Braun et al., 1988). In the digitized pilot study, three untrained raters were used and atypical results were found. Perhaps, the reliability of untrained raters is questionable

and can only be offset by obtaining a large number of raters. Consequently, three raters will receive training and their judgments will be compared to twelve untrained raters.

In summary, the evidence for voluntary emotional facial asymmetries is inconclusive. Although many studies indicate that there is a left-sided bias for emotional facial expressions, several investigations have failed to find such a bias. One variable which separates the positive and negative findings is the rating system employed. Studies relying on subjective ratings have generally found positive results, while studies employing more objective methods have frequently found negative outcomes. It has been proposed that the more objective approaches have lacked the sensitivity required to detect emotional facial asymmetries. If this is the case, then a more sensitive objective measure is required. A study which includes both approaches is necessary to address this research problem. As a result of the apparent lack of sensitivity of other "objective" methods, digitized image analysis was employed as an alternative approach in order to test the major hypotheses presented below.

HYPOTHESES

1) Right Hemisphere hypothesis of emotion: The right hemisphere is specialized for the evaluation and production of emotion. Based on the innervation of the lower portion of the face (greater percentage of contralateral vs. ipsilateral input from the frontal cortex), a left-sided hemiface advantage for voluntary emotional expressions would be consistent with this viewpoint. No expressive asymmetries would be expected for nonemotional facial expressions.

2) Valence hypothesis of emotion: The right hemisphere is specialized for the evaluation, production and experience of negative emotion and the left hemisphere is specialized for these components of positive emotion. This perspective would be supported if a left-sided bias were found for negative emotional expressions and a right-sided bias was found for positive emotional expressions. No expressive asymmetries would be expected for nonemotional facial expressions.

3) Facial Mobility hypothesis of facial expression asymmetries: A bias in neural input either through superior peripheral innervation or a hemispheric specialization of facial movement. Expressive asymmetries would be the result

of an underlying advantage in facial mobility. Individual differences in the direction of the asymmetry would not be inconsistent with this viewpoint. Thus, a left-sided, right-sided or no bias across subjects would all be possible outcomes. However, a strong correlation between emotional and nonemotional facial expression asymmetries would be predicted by this hypothesis.

METHOD

Overview

In order to assess emotional facial asymmetries, subjects were recruited to produce a variety of emotional and nonemotional facial expressions. The stimulus of interest was the video images of their facial expressions. Digitized image analysis and subjective ratings of intensity were utilized to assess facial expression asymmetries. Research assistants were recruited to prepare the stimuli for digitization and raters were recruited to make subjective ratings of the intensity of the facial expressions.

Subjects

Forty right-handed male volunteers between the ages of 18 and 31 were recruited from the university student population. Subjects were either directly asked to volunteer or were recruited from the General Psychology Subject Pool. Because there is evidence of greater variability concerning hemispheric specialization of cognitive functions among left-handers, only right-handers were asked to participate in the experiment. Handedness was assessed with the Briggs and Nebes handedness questionnaire (1975). Additional exclusionary criteria included: (a)

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presence of facial hair which might appear on the digitized image (i.e. mustaches, beards and long sideburns) (b) self-report of a current or past mood disorder (i.e. depression, anxiety); (c) self-reported history of head injury, seizures or other neurological disorders; (d) self-reported history of learning disability.

Stimulus Generation

Subjects were told that they were participating in a study of facial expressions. After obtaining informed consent, subjects were videotaped while sitting down with their head placed in a restraining device. The experiment consisted of three conditions, one involving emotional facial expressions and two involving nonemotional facial expressions. The nonemotional expressions were separated into those that mimicked emotional movements and those which have been used to test for buccal facial praxis. (Buccal Facial Apraxia is a neurological disorder in which there is impairment in the ability to make task oriented facial movements such as blowing out a match). The order of the conditions was randomized and counterbalanced such that one-third of the Ss were asked to produce each emotional expression first, one-third of the Ss were requested to produce the mimicked expressions first and the final third were asked to make the movements used to test buccal facial praxis first.

In the voluntary emotional expression condition, Ss were asked to pose a series of emotional facial expressions. For example, Ss were asked to pose a given emotion in the following manner: "Without moving your head, show me the most intense expression of anger that you can make". After two emotional faces were elicited, the experimenter shortened the elicitation instructions for the rest of the target emotions (e.g. "Show me disgust"). Subjects were not asked to maintain the expressions since only the first 400 msec of the expressions were utilized for the analysis. Five different emotions were elicited (happy, angry, sad, disgust and fear) and the order of elicitation was randomized and counterbalanced. A negative and positive emotion (angry, happy) were chosen for the data analysis. After eliciting all of the emotions once, the procedure was repeated.

In the emotional homologue condition, Ss were asked to display 5 different facial movements. These muscle movements were selected based on their correspondence with the muscle movements associated with the five emotions in the emotional expression condition (Izard, 1977). Ss were asked to (1) squint their eyes (disgust), show as many teeth as possible with mouth closed (happy), (3) raise and (4) knit their eyebrows (fear and anger) and (5) pull both corners of their lips downwards (sad). Once again, Ss received requests to produce each facial movement twice and

the order of presentation was randomized and counterbalanced. The two expressions that mimicked the angry and happy expressions were chosen for the data analysis.

In the buccal praxis condition, Ss were asked to pose five expressions used to test for buccal facial praxis. The expressions were (1) wrinkle brow (2) suck on a straw (3) blow out a match (4) crinkle nose (5) puff out cheeks. Once again, Ss were requested to pose each expression twice and the order of presentation was randomized and counterbalanced. The wrinkle brow and suck on straw expressions were chosen for the data analysis.

Stimulus Preparation

A 400 msec, 13 frame portion of each expression was the stimulus of interest. Each of the 13 frames of each expression was edited into two partial hemifaces such that each hemiface contained a rectangular area from the eyebrow down to the top of the chin and from the outside of the eye across to the middle of the nose and lip filtrum. The exact determination of the facial midline was made by calculating the midpoint of the lip filtrum and the midpoint between the inner canthi of the eyes. The vertical line which was equidistant from these two midpoints was used to divide the face into two hemifaces.

For some of the analyses, the two hemifaces were also divided into a lower and upper portion. Because the area

from the lower eyelid down receives contralateral innervation, a horizontal line dividing the upper and lower portions of the face was constructed. The line dividing the upper and lower portions of the face was tangential to the lowest observable edge of each S's eyes.

Equipment

Video Equipment: An MTI Dage model 68 black and white videocamera with a 35mm lens (promaster spectrum 7) was used for videotaping facial expressions onto a Panasonic AG-6200 VHS video cassette recorder. High Standard VHS videotape (T-120HSN) by TDK was utilized for the videotaping.

Illumination: Two 150 watt Tungsten lightbulbs were employed as the primary light source in order to provide a sufficient and balanced level of lighting. The wattage of lightbulb had been tested previously and had produced a level of brightness that was effective for measuring changes in pixel intensity. The most optimal level of brightness produces a bell-shaped distribution of greyness levels for the digitized image of a light-skinned person. The peak of this curve is located at about the midpoint on the greyness scale. Once the optimal distance was determined, the floor was marked to keep the position of the lightbulbs constant across subjects. Indirect lighting was produced by reflecting the two lightbulbs into white, photography umbrellas. Indirect lighting was used to decrease the level of shadows on the face. To insure that both sides of the

face were receiving equal levels of light, the brightness of the light was measured at the face by a light meter. The light on each side of the face was determined to be within one lux (a unit of measure of brightness).

Head Restraint: A restraining device was used to eliminate significant head movements. The device consisted of a three to five foot adjustable shaft which was attached to a base. Protruding from near the top of the shaft were two adjustable, padded arms that was designed to be placed at both sides of the head. In addition, a head rest was connected to the shaft so the back of the head remained stable. The adjustable arms and shaft allowed the height and the width of the head restraint device to be altered as necessary. Because the head restraint devise was subject to lateral movements, an additional bolt was installed to more securely connect the headrest portion with the main shaft, and thereby, increase stability.

Computer Software: For the purposes of editing and digitizing the videotape images, the Xybion Image Capture Analysis System (XICAS) was employed. This system allowed for the capture of a 13 frame, 400 msec sequence of a videotaped image. It was also capable of creating mirror reversals of the images so that composite faces (left-left and right-right) were constructed from each hemiface.

Video Monitor: A 15" x 19" Conrac monochrome monitor (model 2600) was utilized for viewing the images. In

conjunction with XICAS, the monitor provided approximately 30,000 pixels for the analysis of a given facial area.

Videographic Printer: A series of 2.5" x 2.5" digitized photographs of the facial expressions were produced by a Sony videographic printer (UP 701N) onto 110mm Type I Sony photograph paper (UPP-110S).

Research Assistants

Four undergraduate psychology students were recruited to assist in the capture and analysis of the digitized images as well as the creation of hemiface composites from videotapes of facial expressions. They were blind to the experimental hypotheses and were trained to utilize the computer program for digitized image analysis. For their participation, assistants received three credit hours toward a course in psychology research.

The training process began with an orientation to the computer equipment. Assistants were taught the commands necessary to operate the computer program for the capture and digitization of videotaped images. In addition, they were given practice videotapes of facial expressions until they demonstrated an adeptness at capturing the facial expressions at the appropriate moment. The appropriate moment was defined as the initiation of the expression. From a training perspective, the advantage of defining the initiation of the expression as the appropriate moment for

capture was that assistants obtained tangible evidence of an effective capture (changes in pixel intensities).

The criteria of an effective capture was determined by the rate of increase in the mean difference scores across the 13 frames. When the mean difference scores are plotted and the image is captured at the onset, the plot displays a gradual rise time across the first few frames and then an acceleration. On the other hand, a rapid rise time from the first frame is indicative of an expression captured after its onset. To insure that the target expression was captured prior to its initiation, the investigator examined the rise time of the quantitative measure of facial movement. A capture was considered successful if the sum of the difference score for the first 3 frames was less than one-sixth of the grand total difference score. Upon completion of three consecutive captures in which a gradual rise time was displayed, Ss were deemed ready to work with the experimental facial expressions.

In addition to being trained to capture digitized images, assistants were trained to make composite photos of the facial expressions. This involved dividing the face in half and creating whole faces from one hemiface and its mirror reversal. An important step in this process involved the selection of a midline that most accurately divided the face. The experimenter reviewed the practice composite images and measured the distance between the midline and two

facial referents (the midpoint between the inner canthi of each eye and the midpoint of both edges of the lip filtrum) to insure that the midline was equidistant from these two points. Assistants were given non-experimental digitized images to practice the selection of an accurate midline. Following three consecutive selections in which the position of the midline chosen by the assistants matched that of the experimenter, assistants began the creation of composite images.

Digitization of Pixel Intensities

Although Ss posed each facial expression twice, blinded research assistants were instructed to select from the videotape only one image per expression. The criteria for selection included degree of head movement, clarity of onset and rapidity of the expressions. Assistants made this determination based on their impression of these factors. Once an expression was chosen, the assistants examined the videotape in slow motion to determine the initiation of the expression. From that point, 13 still frames (30.75 msec apart) from a 400 msec portion of the expression was captured for analysis by the experimenter. A 400 msec portion of the videotape is the maximum amount of time that XICAS is capable of capturing an expression.

To obtain a quantitative measure of expression change, the difference in greyness level at each pixel location was calculated for two adjacent frames of the expression

vignette. A mean difference score between two adjacent frames was computed by summing all the difference scores at each pixel location and dividing by the total number of pixels utilized. For each of the target expressions, a summation of the absolute value of the mean difference scores across 13 frames (the grand total difference score) was computed for each hemiface. The grand total difference score was considered a measure of entropy. Greater entropy is associated with greater facial movement. An asymmetry score was calculated using the following formula: (L-R)/ (L+R) with L representing the grand total difference score for the left hemiface and R representing the grand total difference score of the right hemiface.

Subjective Ratings

In addition to the digital analysis, subjective ratings of expressivity were also collected. This was done by first having the research assistants construct composite images from the final frame of each facial expression. A composite image is constructed from one hemiface and its mirror reversal. Composite images of both the left and right hemifaces were assembled for each facial expression. Using the videographic printer, a digitized photograph was produced for each hemiface composite. Each pair of composite photographs (one left hemiface composite and one right hemiface composite) was mounted onto a 5" x 8" index card. The left and right hemiface composite photographs

were vertically positioned on the card such that one was directly above the other. The top and bottom positions were randomly determined.

Raters

Twelve untrained (eight female and four male) and three trained raters (two female and one male) were employed to make subjective ratings of facial expressivity. Untrained raters were obtained from the General Psychology Subject Pool and their participation satisfied a class requirement. Trained raters received three credit hours towards a course in psychology research. The trained raters were screened on the facial subtests of the Florida Affect Battery (Bowers, Blonder and Heilman, 1991). The Florida Affect Battery consists of a series of affect perception tests and is an assessment instrument of the ability to perceive and interpret facial emotions. Prospective raters were not accepted if they scored under one standard deviation below the mean on any facial subtest in the battery.

Viewing video images of emotional expressions formed the core of the training procedure for the trained raters. The raters were shown 13 separate images of an expression vignette. This process was repeated with additional vignettes and included a variety of posers and emotions (i.e. happy, angry, sad, disgust and fear). Thus, the trained raters were exposed to a range of emotional

intensities, a collection of individual faces, and a set of particular emotions.

Raters were instructed to attend to the movement of various facial features that were associated with given emotions. For example, they were asked to concentrate on the lowering of the eyebrows, the narrowing of the eyes and the widening of the nose for an angry face. For sadness, raters were directed to examine the lowering of each end of the lips and the wrinkling of the brow. The experimenter advised the raters to attend to the widening of the eyes, raising of the eyebrows and the opening of the mouth for fear expression. Raters were also instructed to concentrate on the crinkling of the nose, the raising of the cheeks, the lowering of the ends of the lips and the lowering of the brow for a disgusted face. For happiness, raters were directed to examine the raising of the cheeks and the raising of the ends of the lips.

Following this procedure, raters were given a pair of faces of the same individual posing the same emotional expression at different points in time. They were instructed to choose the most intense. They viewed a total of 20 faces. If they obtain an 85% accuracy rate (selection of the face at the later point in time), they proceeded to the experimental facial expressions. Otherwise, they received additional training and were retested for adequate accuracy. One rater achieved the cutoff on the first

attempt, a second rater achieved it on the second and the last rater reached the cutoff on the fourth attempt.

Ratings Procedure

Each rater (trained and untrained) was shown each card and asked to choose which of the two faces was more intensely expressive. Because there were 40 subjects portraying two emotional and four nonemotional movements, 240 target stimulus cards were created. Duplicates of 24 cards (four of each expression - emotional and nonemotional) were included in the rating task in order to assess intrarater reliability. Thus, a total of 264 stimulus cards were presented to the raters. All of the cards associated with a particular expression formed a set. The raters viewed all of the cards from one set before making ratings on the next set. The order of the sets were counterbalanced and randomized.

RESULTS

In the digital analysis, the primary dependent measures of facial activity were the entropy score and the asymmetry score. As previously described, an entropy score was calculated for each expression posed by each subject. The entropy score was based on the average change in pixel intensity across all the relevant pixels in an expression. The change in pixel intensity was calculated by summing the absolute value of the difference scores for each individual pixel. A difference score was determined by subtracting the difference in pixel intensities of adjacent frames in a facial expression. There were 13 frames per expression. An entropy score can be computed for any portion of the face. Table 1 depicts whole face entropy scores by expression.

TABLE 1

Entropy Change for Whole Face

	M	sd	Min	Max
Angry	104.37	(52.54)	50.63	268.95
Happy	156.49	(84.33)	39.64	356.64
Lower Eyebrows	100.17	(46.25)	42.99	267.21
Show Teeth	180.71	(62.49)	68.13	358.13
Wrinkle Brow	134.75	(79.91)	46.26	373.76
Suck on Straw	91.22	(36.76)	47.47	247.74

Laterality of Emotional Expressions based on Entropy Score

The first question of interest explored whether there were lateral asymmetries associated with emotional expressions, and if so, was the direction of the asymmetry associated with the valence of the emotion. The second question asked whether lateral asymmetries interacted with the area of the face examined (i.e. top, bottom). To address both of these questions, a 3-way (2x2x2) Repeated Measures Analysis of Variance (ANOVA) was performed with entropy score as the dependent measure. The within factors were emotion (angry, happy), side of face (left, right) and vertical portion of face (top, bottom). A significant main effect was found for emotion [F(1,39) = 8.11, p= .007] indicating that the happy expression (M= 152.00, sd= 91.34) was more active than the angry expression (M= 108.33, sd= 56.28). The analysis revealed two significant interactions which will be discussed below.

The first significant interaction was between the side of face and vertical portion of face [F(1,39) = 5.75, p= .021]. Post hoc t-tests indicated that the only significant difference in quadrant activity was between the top right (M= 143.45, sd= 104.53) and top left (M= 130.35, sd= 98.44) quadrants with the top right being greater [t(39) = -2.98, p= .005].

The second significant interaction was between emotion and vertical portion of face [F(1,39) = 5.33, p= .026]. The

means of the upper and lower portions of the face for the angry and happy expressions are displayed in Table 2. Post hoc t-tests suggested that the emotion x vertical interaction was a consequence of lower activity in the lower portion of the face during an angry expression. The bottom angry expression was less active than the top angry [t(39) = 2.44, p= .019], top happy [t(39) = 2.18, p= .035] and bottom happy [t(39) = 5.06, p< .001] expressions. No other pairs were significantly different.

TABLE 2

Mean Entropy Change

	ANGRY	HAPPY
TOP	130.94 (102.31) a	142.86 (149.32) b
BOTTOM	85.73 (52.18) c	161.15 (95.23) d

Post hoc summary: a>c*, b>c*, d>c***, a=b=d

+ - p< .10   * - p< .05   ** - p< .01   *** - p< .001

In summary, the results of the entropy score analysis indicated that the activity level was small in the bottom of the face of the angry expression. The activity level was lower there than in the top of the angry expression and both the top and bottom of the happy expression. In relation to question #1, the analysis also indicated that a right-sided bias was found in the upper face for both the angry and

happy expression. No significant lateral effects were found in the lower face.

Laterality of Emotional Expressions based on Asymmetry Score

One possible confound using raw entropy scores is that differences in facial asymmetry as measured by changes in pixel intensity might be weighted in favor of the more expressive subjects. To address this concern, a second Repeated Measures ANOVA was conducted using an asymmetry score as a dependent measure. The asymmetry score was calculated by subtracting the entropy score on the right side of the face from the entropy score on the left side of the face, and then dividing the difference by the sum of the entropy scores on the left and right side of the face. An asymmetry score can be determined for the whole face or portions of the face (i.e. top, bottom). The asymmetry score was calculated for each expression produced by each subject.

With the asymmetry scores as the dependent variable, a 2x2 Repeated Measures ANOVA was performed. The two within subject factors were expression (angry, happy) and vertical portion of face (top, bottom). The side of face variable was embedded within the dependent measure itself.

Results of the analysis revealed a significant main effect for vertical portion of face [$F(1,39) = 9.25$, $p= .004$] indicating that the top portion ($M= -0.03$, $sd= 0.08$) of the expression was significantly more right-biased than

the bottom portion (M= 0.02, sd= 0.08), regardless of emotional expression.

The vertical x emotion interaction was also found to be significant [F(1,39) = 5.04, p= .031]. The means of the upper and lower portions of the face for the angry and happy expressions are displayed in Table 3. Post hoc t-tests revealed that the bottom angry expression was significantly more left-biased than the top angry [t(39) = 4.17, p< .001], top happy [t(39) = 2.55, p= .015] and bottom happy [t(39) = 2.08, p= .045] expressions. The top angry expression was nearly significantly more right-sided than the bottom happy expression [t(39) = -1.99, p= .054]. There were no other significant differences.

TABLE 3

Asymmetry Scores

	ANGRY	HAPPY
TOP	-0.05 (0.10) a	-0.02 (0.11) b
BOTTOM	0.04 (0.10) c	0.00 (0.11) d

Post hoc summary: c>a*, c>b***, c>d*, d>a+, a=b, b=d

+ - p< .10   * - p< .05   ** - p< .01   *** - p< .001

The prior analyses measured differences in the asymmetry scores between two factors. A significant difference in the asymmetry scores between two factors, however, does not guarantee that any individual factor is

significantly asymmetrical. For example, two factors which are not significantly asymmetrical may be significantly different from one another if one score displays a left-sided tendency and the other displays a right-sided tendency. One sample t-tests allow a measurement of asymmetry for an individual expression. Thus, to determine whether an individual expression was asymmetrical, one sample t-tests were conducted for the upper and lower portions of the face.

The results indicated that only the angry expression was significantly asymmetrical and the direction of the bias was dependent upon the vertical position. As suggested in Table 3, the bottom angry expression (M= 0.04, sd= 0.10) was significantly left-sided [t(39) = 2.51, p= .016] and the top angry expression (M= -0.05, sd= 0.11) was significantly right-sided [t(39) = -2.88, p= .006].

In summary, when controlling for overall expressivity (by using an asymmetry score as the dependent variable), there was a significant left-sided bias in the lower portion of the face for the angry expression. The asymmetry score analysis also indicated that only the angry expression displayed a significant right-sided asymmetry in the upper face. (The asymmetry score of the happy expression in the upper face was consistent with the direction of the angry expression). The results from the entropy score analysis suggested that the right-sided bias in the upper face was

evident regardless of the emotional expression. However, in contrast to the asymmetry score data, the entropy score analysis revealed no evidence of a bias in the lower portion of the face for either expression.

Influence of Lighting on Expressive Asymmetries

Critics have proposed that lighting biases are responsible for detected expressive asymmetries (Spinrad, 1980). A lighting bias is an asymmetry in light intensity such that one side of the face receives brighter lighting than the other. A method utilizing changes in pixel intensities is particularly susceptible to contamination by uneven lighting because the baseline pixel intensities would differ between the sides. As discussed previously, the pixel intensity is directly correlated with the brightness of lighting.

Thus, a baseline measure of mean pixel intensity for each side of the face was calculated to determine the existence of a possible lighting bias. The baseline measure was calculated by subtracting the average pixel intensity of the right side of the face from the average pixel intensity of the left side of the face. The baseline measure was taken during a neutral expression prior to the posing of the target expressions. A one sample t-test was conducted with the difference in baseline mean pixel intensity as the dependent measure. The results indicated that the

difference (M= -3.39, sd= 10.49) was significantly biased towards the right side of the face [t(39) = -2.04, p=.048].

Having established the existence of a lighting bias, an association between the asymmetry scores and the lighting was evaluated. The asymmetry scores for the angry and happy expressions (top, bottom and whole face) were correlated with the lighting difference. Additional expressions included in the study (lower eyebrows, show teeth, wrinkle brow and suck on straw) were also correlated with the difference in lighting.

Correlations between lighting and the asymmetry scores of the whole face were found for the happy (r= .4520, p= .003) and show teeth (r= .4071, p= .009) expressions. Only one correlation between lighting and the asymmetry scores for the top portion of the face obtained significance and that was for the suck on straw expression (r= .3666, p= .046). In the bottom of the face, the happy (r= .5183, p=.001), lower eyebrow (r= .4122, p= .008), show teeth (r= .5217, p= .001) and suck on straw (r= .4915, p= .001) expressions were all significantly correlated with lighting.

Taken together, the results suggest greater light intensity on the right side of the face, which appeared to be biasing the asymmetry scores in that direction. The bias was particularly evident in the lower portion of the face. For example, significant correlations were found there suggesting that a right-sided lighting bias may be masking

actual left-sided expressive asymmetries in the lower face. Table 4 depicts the correlations between the asymmetry scores of each expression and the lighting bias.

TABLE 4

Correlation - Asymmetry Score & Lighting Bias

Expression	Whole	Top	Bottom
Angry	.1857	.0113	.2672+
Happy	.4520**	.1282	.5183**
Lower Eyebrow	.2945+	.1610	.4122**
Show Teeth	.4071**	.1344	.5217**
Wrinkle Brow	.2216	.1905	.2087
Suck on Straw	.3007+	.3666*	.4915**

+ - p< .10   * - p< .05   ** - p< .01   *** - p< .001

Emotional Expression Laterality with Correction for Lighting

Given the potential of a lighting confound, a method was sought to statistically adjust for the bias. Because baseline differences in the measure of interest was the potential confound, a statistical method which compensated for the baseline differences was deemed most appropriate.

One research area which has often encountered the difficulty of individual baseline differences is that which utilizes psychophysiological measures. To adjust for individual baseline differences, Lacey (1956), a notable psychophysiological researcher, developed a formula for

calculating a residualized gain score. The residualized gain score is the measure of interest after the individual baseline differences have been factored out. The formula is as follows:

$$Z_d = 50 + 10 \left(\frac{Y_d - X_d * R_{xy}}{\sqrt{1 - R_{xy}^2}} \right)$$

where Z= residualized gain score; Y= dependent measure; X= baseline level of dependent measure; R= correlation; d= per individual subject.

Using Lacey's formula for calculating the residualized gain score, the first two questions were re-examined while statistically adjusting for individual differences in baseline lighting intensity. A 3-way (2x2x2) Repeated Measures Analysis of Variance (ANOVA) was then performed with the adjusted entropy score as the dependent measure. The within factors were emotion (angry, happy), side of face (left, right) and vertical portion of face (top, bottom). A significant main effect was found for emotion [F(1,39) = 8.86, p= .005] indicating that the happy expression (M= 1639.42, sd= 929.33) was more active than the angry expression (M= 1175.68, sd= 565.12). A significant main effect was also found for vertical portion of face [F(1,39) = 4.08, p= .05] suggesting that the top part of the face (M= 1594.08, sd= 1016.68) displayed greater movement than the bottom portion (M= 1221.02, sd= 589.18). A third main effect was found for side of face [F(1,39) = 20.87, p< .001]

indicating that right side (M= 1482.17, sd= 609.16) was more active than the left side (M= 1332.93, sd= 589.94). The analysis revealed two significant interactions which will be discussed below.

The first significant interaction was between the side of face and vertical portion of face [F(1,39) = 24.17, p< .001]. The means of each quadrant are displayed in Table 5. Post hoc t-tests were conducted with a correction for multiple comparisons utilizing the Bonferroni method. The t-tests suggested that the side x vertical interaction was a consequence of greater activity in the top right quadrant. The top right portion of the face was more active than the top left [t(39) = -7.09, p< .006] and bottom left [t(39) = -2.80, p= .048]. A trend suggested that the top right was also more active than the bottom right [t(39) = 2.75, p= .054] expressions. No other pairs were significantly different.

TABLE 5

Mean Adjusted Entropy Change

	LEFT	RIGHT
TOP	1435.42 (987.77) a	1752.74 (1063.80) b
BOTTOM	1230.44 (600.00) c	1211.61 (619.38) d

Post hoc summary: b>a***, b>c*, b>d+, a=c=d

+ - p< .10   * - p< .05   ** - p< .01   *** - p< .006

The second significant interaction was between emotion and side of face [$F(1,39) = 4.21$, p= .047]. The means of the left and right portions of the face for the angry and happy expressions are displayed in Table 6. Bonferroni corrected t-tests suggested that the emotion x side interaction was a consequence of greater activity in the right side of the face during a happy expression. The right happy expression was more active than the right angry [$t(39) = -3.13$, p= .018], left angry [$t(39) = -3.97$, p< .006] and left happy [$t(39) = -4.50$, p< .006] expressions. There was also a trend for the left happy to display greater entropy than the left angry [$t(1,39) = -2.70$, p= .06]. No other pairs were significantly different.

TABLE 6

Mean Adjusted Entropy Change

	LEFT	RIGHT
ANGRY	1131.20 (524.41) a	1220.16 (630.58) b
HAPPY	1534.66 (930.86) c	1744.18 (950.84) d

Post hoc summary: d>a***, d>b*, d>c***, c>a+, a=b, b=c

\+ - p< .10   * - p< .05   ** - p< .01   *** - p< .006

Taken together, a comparison of the entropy change data with and without the adjustment suggests some change in the results associated with the correction for individual baseline differences in lighting. For example, only the

adjusted analyses indicated greater activity in the right side of the happy expression. In addition, the vertical x emotion interaction disappeared in the adjusted analyses. Both the adjusted and non-adjusted data indicated that the top right quadrant displayed the greatest entropy. To pursue whether the adjustments for lighting significantly impacted the questions of interest, a conversion of the corrected entropy score into a corrected asymmetry score was conducted. The calculation of the adjusted asymmetry score was performed as previously described with the adjusted entropy scores inserted in place of the original entropy scores.

Emotional Laterality based on Adjusted Asymmetry Score

With the adjusted asymmetry scores as the dependent variable, a 2x2 Repeated Measures ANOVA was performed. The two within subject factors were expression (angry, happy) and vertical portion of face (top, bottom). The side of face variable was embedded within the dependent measure itself.

Results of the analysis revealed a significant main effect for emotion [$F(1,39) = 22.69$, $p < .001$] indicating that the happy expression (M= -0.08, sd= 0.08) was more right-biased than the angry expression (M= -0.01, sd= 0.07). A significant main effect was also found for vertical portion of face [$F(1,39) = 69.06$, $p < .001$] suggesting that the top portion (M= -0.11, sd= 0.07) of the expression was

significantly more right-biased than the bottom portion (M= 0.02, sd= 0.09), regardless of emotional expression.

In addition to the main effects, the vertical x emotion interaction was found to be significant [F(1,39) = 8.67, p= .005]. The means of the upper and lower portions of the face for the angry and happy expressions are displayed in Table 7. Also included in the table is the number of subjects determined to be left-biased or right-biased. The bias was determined by the asymmetry score: any score greater than zero was considered left-biased and any score less than zero was considered right-biased.

An a priori t-test was conducted to examine whether a difference in asymmetry in the bottom of the face was associated with the valence of the emotion. The results indicated that the bottom angry expression was significantly more left-biased than the bottom happy [t(39) = 5.16, p< .001] expression. Post hoc t-tests with a bonferroni correction also revealed that the bottom angry expression was significantly more left-biased than the top angry [t(39) = 8.46, p< .006] and top happy expression [t(39) = 9.51, p< .006]. The bottom happy expression was also found to be less right-biased than the top angry [t(39) = 3.04, p= .024] and top happy [t(39) = 4.17, p< .006] expressions. There were no other significant differences.

TABLE 7

Adjusted Asymmetry Scores

	ANGRY				HAPPY		
	$\underline{M}$	$\underline{sd}$	$\underline{L/R}$		$\underline{M}$	$\underline{sd}$	$\underline{L/R}$
TOP	-0.10	(0.09)	4/36 a		-0.12	(0.09)	4/36 b
BOTTOM	0.07	(0.10)	37/3 c		-0.03	(0.11)	14/26 d

Post hoc summary: c>a***, c>b***, c>d***, d>a*, d>b***, a=b

+ - p< .10   * - p< .05   ** - p< .01   *** - p< .006

The prior analyses measured differences in the asymmetry scores between two factors. As discussed previously, a significant difference in the asymmetry scores between two factors does not guarantee that any individual factor is significantly asymmetrical. Thus, to determine whether an individual expression was asymmetrical, two a priori one sample t-tests were conducted for the lower portion of the face and two post hoc one sample t-tests with a bonferroni correction were conducted for the upper portion of the face.

The results indicated that the direction of the asymmetry was dependent upon the valence of the emotion and the vertical position of the face. As suggested in Table 7, the bottom angry expression was significantly left-sided [t(39) = 4.51, p< .001], while the top angry [t(39) = -7.20, p< .006] and top happy [t(39) = -8.54, p< .006] expressions were significantly right-sided. A trend for right-sidedness

was found for the bottom happy expression [t(39) = -1.92, p= .062].

In summary, when controlling for overall expressivity (by using an asymmetry score as the dependent variable) and correcting for baseline differences in lighting (by calculating the residualized gain score), there was a significant left-sided bias in the lower portion of the face for the angry expression. Consistent with the Valence hypothesis, there was a trend toward right-sidedness in the bottom portion of the happy expression. The asymmetry score analysis also indicated that both the angry and happy expressions displayed a significant right-sided asymmetry in the upper face. Consistent with the adjusted asymmetry scores, the results from the entropy score analysis suggested that the right-sided bias in the upper face was evident regardless of the emotional expression. However, in contrast to the asymmetry score data, the entropy score analysis revealed no evidence of a bias in the lower portion of the face for either expression.

Asymmetry Scores for Additional Emotional Expressions

Because additional emotional expressions were obtained from the study subjects, these expressions were analyzed to determine the consistency of the above findings. To conduct the analysis, adjusted asymmetry scores were calculated for the two expressions utilizing the procedure previously discussed. The two expressions, sadness and fear, are both

"negative", and thus, a left-sided bias in the lower face would be consistent Valence hypothesis suggested by the analysis of the adjusted asymmetry scores.

With the adjusted asymmetry scores as the dependent variable, a 2x2 Repeated Measures ANOVA was performed. The two within subject factors were expression (sad, fear) and vertical portion of face (top, bottom). The side of face variable was embedded within the dependent measure itself.

Results of the analysis revealed a significant main effect for vertical portion of face [$F(1,39) = 37.83$, $p< .001$] indicating that the top of the face (M= -0.09, sd= 0.10) was more right-biased than the bottom of the face (M= 0.03, sd= 0.07), regardless of emotional expression. There was no other main effects or interactions.

The prior analyses measured differences in the asymmetry scores between two factors. As discussed previously, a significant difference in the asymmetry scores between two factors does not guarantee that any individual factor is significantly asymmetrical. Thus, to determine whether an individual expression was asymmetrical, one a priori one sample t-test was conducted for the lower portion of the face and one post hoc one sample t-test with a Bonferroni correction was conducted for the upper portion of the face.

The results indicated that the direction of the asymmetry was dependent upon the vertical position of the

face. The bottom of the face was significantly left-sided
[t(39) = 2.61, p= .013], while the top of the face [t(39) =
-5.59, p< .006] was significantly right-sided. Taken
together, the results were consistent with the previous
analysis suggesting both a left-sided bias for negative
emotional expressions in the lower portion of the face and a
right-sided bias in the upper portion of the face regardless
of emotional valence.

Nonemotional Laterality based on Adjusted Entropy Score

The third question asked whether asymmetries in facial
expressions were associated with nonemotional as well as
emotional facial expressions. One assumption underlying
much of the neuropsychological research on facial
asymmetries is that expressive biases are the result of an
hemispheric specialization for emotional processing. There
is some evidence, however, that asymmetries in facial
musculature and/or the peripheral nervous system are
responsible for, or at least could contribute to, facial
asymmetries.

To explore this question, a similar analysis was
conducted with two expressions which were designed to mimic
the prior expressions without an emotional aspect. For
example, subjects were asked to lower their eyebrows in
order to mimic the prominent upper face movements associated
with the angry expression. This procedure was included to
assess whether the laterality associated with the prior

analyses can be attributed to the emotional nature of the expressions.

A 3-way (2x2x2) Repeated Measures Analysis of Variance (ANOVA) was then performed with the adjusted entropy score as the dependent measure. The within factors were emotion homologues (lower eyebrows, show teeth), side of face (left, right) and vertical portion of face (top, bottom). A significant main effect was found for emotion homologues [$F(1,39) = 19.67$, $p< .001$] indicating that the show teeth expression ($M= 1534.99$, $sd= 546.08$) was more active than the lower eyebrow expression ($M= 1091.56$, $sd= 511.93$). A significant main effect was also found for vertical portion of face [$F(1,39) = 4.08$, $p= .05$] suggesting that the top part of the face ($M= 1594.08$, $sd= 1016.68$) displayed greater movement than the bottom portion ($M= 1221.02$, $sd= 589.18$). No other significant main effects were found. The analysis revealed two significant interactions which will be discussed below.

The first significant interaction was between the side of face and vertical portion of face [$F(1,39) = 6.69$, $p< .014$]. The means of each quadrant are displayed in Table 8. Post hoc t-tests were conducted with a correction for multiple comparisons utilizing the Bonferonni method. The only notable finding was a trend for the top right portion of the face to be more active than the top left [$t(39) = -2.70$, $p= .06$]. No other pairs were significantly different.

TABLE 8

Mean Adjusted Entropy Change

	LEFT	RIGHT
TOP	1167.74 (637.48) a	1288.34 (692.95) b
BOTTOM	1412.11 (569.71) c	1384.92 (523.97) d

Post hoc summary: b>a+, b=c, b=d, a=c=d

+ - p< .10   * - p< .05   ** - p< .01   *** - p< .006

The second significant interaction was between emotion homologues and vertical portion of face [$F(1,39) = 151.97$, p< .001]. The means of the top and bottom portions of the face for the lower eyebrows and show teeth expressions are displayed in Table 9. Bonferroni corrected t-tests suggested that the mimicry x vertical interaction was primarily a consequence of greater activity in the bottom portion of the face during the show teeth expression with some contribution by the upper portion of the face during the lower eyebrow expression. The bottom portion of the show teeth expression was more active than the bottom lower eyebrows [$t(39) = -11.62$, p< .006], the top lower eyebrows [$t(39) = -3.08$, p= .024] and the top show teeth [$t(39) = -7.25$, p< .006] expressions. The top of the lower eyebrows expression also displayed significantly more entropy than the top show teeth [$t(1,39) = -5.70$, p< .006] and bottom lower eyebrows [$t(1,39) = -8.21$, p< .006] expressions. No other pairs were significantly different.

TABLE 9

Mean Adjusted Entropy Change

	LOWER EYEBROWS	SHOW TEETH
TOP	1622.57 (864.87) a	833.50 (694.34) b
BOTTOM	560.54 (332.89) c	2236.49 (929.16) d

Post hoc summary: d>a*, d>b***, d>c***, a>b***, a>c***, b=c

+ - p< .10   * - p< .05   ** - p< .01   *** - p< .006

In summary, consistent with expectations, the entropy score data indicated that the activity of the lower eyebrow expression is concentrated in the upper face and the activity of the show teeth expression is concentrated in the lower face. The results did not suggest any significant asymmetries in the lower portion of the face for nonemotional expressions. In addition, it is unclear if there exists a right-sided bias in the upper portion of the face. To pursue the question of interest in a more accurate manner, a conversion of the corrected entropy score into a corrected asymmetry score was conducted. The calculation of the adjusted asymmetry score was performed as previously described with the adjusted entropy scores inserted in place of the original entropy scores.

Nonemotional Laterality based on Adjusted Asymmetry Score

With the adjusted asymmetry scores as the dependent variable, a 2x2 Repeated Measures ANOVA was performed. The two within subject factors were emotion homologues (lower

eyebrows, show teeth) and vertical portion of face (top, bottom). The side of face variable was embedded within the dependent measure itself.

Results of the analysis revealed a significant main effect for vertical portion of face [$F(1,39) = 15.60$, $p < .001$] suggesting that the top portion (M= -0.05, sd= 0.08) of the expression was significantly more right-biased than the bottom portion (M= 0.00, sd= 0.06), regardless of emotional expression. There were no other significant main effects or interactions.

The prior analyses measured differences in the asymmetry scores between two factors. As discussed previously, a significant difference in the asymmetry scores between two factors does not guarantee that any individual factor is significantly asymmetrical. Thus, to determine whether the lower face expression was asymmetrical, one a priori one sample t-test was conducted. No significant asymmetry was found. In addition, one post hoc one sample t-test with a Bonferroni correction was conducted to determine if the upper portion of the face was asymmetrical. The results indicated that the upper face (M= -0.05, sd= 0.08) was right-biased [$t(39) = -4.10$, $p < .006$].

In regards to the third question, there was evidence that expressive asymmetries in the lower face are the product of emotional factors. For example, neither nonemotional expression displayed a significant asymmetry in

the lower portion of the face. In the upper face, however, there was a significant right-sided bias for both nonemotional expressions.

Adjusted Entropy Scores of Additional Expressions

Because there was concern that the expressions designed to mimic emotional expressions may not have been completely void of an emotional content, another pair of facial expressions which were thought to be emotionally neutral were examined in a similar manner as the aforementioned analyses. These movements have been examined in the context of assessing Buccal Facial Praxis. (Buccal Facial Apraxia is a neurological disorder in which there is impairment in the ability to make task oriented facial movements such as blowing out a match). A 3-way (2x2x2) Repeated Measures ANOVA was conducted with side of face, vertical portion of face and expression type (suck on straw, wrinkle brow) as the independent variables and the adjusted entropy score as the dependent variable.

The analysis revealed a significant main effect for expression type [$F(1,39) = 21.26$, $p< .001$] indicating that the wrinkle brow expression ($M= 1506.19$, $sd= 1036.22$) displayed greater entropy than the suck on straw expression ($M= 729.35$, $sd= 404.18$). A significant main effect was also found for vertical portion of face [$F(1,39) = 19.10$, $p< .001$] suggesting that the upper face ($M= 1531.83$, $sd= 1158.44$) was more active than the lower face ($M= 703.71$, $sd=

213.25). Finally, a significant main effect was found for side of face [F(1,39) = 12.17, p= .001] indicating that the right side of the face (M= 1167.95, sd= 628.92) was more active than the left side of the face (M= 1067.58, sd= 539.01). The analysis revealed three significant interactions which will be discussed below. The 3-way interaction was not significant.

The first significant interaction was between expression type and vertical portion of face [F(1,39) = 27.58, p< .001]. The means of each quadrant are displayed in Table 10. Post hoc t-tests were conducted with a correction for multiple comparisons utilizing the Bonferroni method. The t-tests revealed greater activity in the upper face of the wrinkle brow expression. The top portion of the wrinkle brow expression was more active than the top straw [t(39) = -4.99, p< .006], bottom wrinkle [t(39) = -5.06, p< .006] and bottom straw [t(39) = -4.70, p< .006] expressions. No other pairs were significantly different.

TABLE 10

Mean Adjusted Entropy Change

	WRINKLE BROW	SUCK ON STRAW
TOP	2349.94 (2079.63) a	713.71 (713.38) b
BOTTOM	662.44 (219.14) c	744.98 (315.49) d

Post hoc summary: a>b***, a>c***, a>d***, b=c=d

+ - p< .10   * - p< .05   ** - p< .01   *** - p< .006

The second significant interaction was between expression type and side of face [F(1,39) = 40.95, p< .001]. The means of the left and right portions of the face for the angry and happy expressions are displayed in Table 11. Bonferroni corrected t-tests suggested that the expression type x side interaction was a consequence of greater activity in the right side of the face during a wrinkle brow expression. The right wrinkle brow expression was more active than the right suck on straw [t(39) = -5.25, p= .006], left wrinkle brow [t(39) = -5.06, p< .006] and left suck on straw [t(39) = -4.72, p< .006] expressions. The left wrinkle brow expression was also significantly more active than the left suck on straw [t(39) = 3.83, p= .006] and right suck on straw expression [t(39) = 4.38, p< .006]. The left suck on straw expression displayed significantly greater activity than the right suck on straw expression [t(39) = 2.98, p= .03].

TABLE 11

Mean Adjusted Entropy Change

	LEFT	RIGHT
WRINKLE BROW	1380.00 (962.90) a	1632.38 (1126.95) b
SUCK ON STRAW	755.17 (431.01) c	703.53 (383.36) d

Post hoc summary: b>a,c,d***, a>c,d***, c>d

+ - p< .10   * - p< .05   ** - p< .01   *** - p< .006

The third significant interaction was between side of face and vertical portion of face [F(1,39) = 4.82, p=.034]. The means of the four quadrants of the face (top left, top right, bottom left and bottom right) are displayed in Table 12. Bonferroni corrected t-tests suggested that the side x vertical interaction was a consequence of proportionately greater left-right difference in the lower face despite the greater expressivity in the upper face. The lower right side of the face displayed more activity than the lower left side of the face [t(39) = 3.43, p= .006]. In the upper face, the right side was also more active [t(39) = 3.09, p= .024]. In addition, the upper right side of the face was significantly more active than the bottom left [t(39) = 3.83, p= .006] and right side of the face [t(39) = 4.39, p< .006]. Finally, the upper left side of the face displayed significantly greater activity than the lower left [t(39) = 4.31, p< .006] and right side of the face [t(39) = 4.19, p< .006].

TABLE 12

Mean Adjusted Entropy Change

	LEFT	RIGHT
TOP	1459.88 (1089.16) a	1603.77 (1241.39) b
BOTTOM	675.29 (242.69) c	732.13 (193.75) d

Post hoc summary: b>c,d***, a>c,d***, d>c**, b>a*

\+ - p< .10   * - p< .05   ** - p< .01   *** - p< .006

In summary, the adjusted entropy scores indicated that the wrinkle brow expression displayed greater activity than the suck on straw expression. Furthermore, the activity of the wrinkle brow expression appeared to be more concentrated in the upper right quadrant. Consistent with previous findings, there was evidence of a right-sided bias in the upper portion of the face for both of the expressions. In regards to the third question, the results did not suggest a consistent direction of asymmetry in the lower portion of the face for these two nonemotional expressions. To pursue the third question of interest in a more accurate manner, a conversion of the corrected entropy score into a corrected asymmetry score was conducted. The calculation of the adjusted asymmetry score was performed as previously described with the adjusted entropy scores inserted in place of the original entropy scores.

Adjusted Asymmetry Scores of Additional Expressions

With the adjusted asymmetry scores as the dependent variable, a 2x2 Repeated Measures ANOVA was performed. The two within subject factors were expression type (wrinkle brow, suck on straw) and vertical portion of face (top, bottom). The side of face variable was embedded within the dependent measure itself.

Results of the analysis revealed a significant main effect for expression type [$F(1,39) = 64.05$, $p< .001$] indicating that the wrinkle brow expression (M= -0.11, sd=

0.10) was more right-biased than the suck on straw expression (M= 0.02, sd= 0.07). In addition to the expression type main effect, a vertical x expression interaction was found to be significant [$F(1,39) = 48.67$, $p < .001$] and will be discussed below. The means of the upper and lower portions of the face for the wrinkle brow and suck on straw expressions are displayed in Table 13. Also included in the table is the number of subjects determined to be left-biased or right-biased.

Two a priori t-tests were conducted to examine whether the nonemotional expressions were asymmetrical in the bottom of the face. The results of the pairwise t-tests indicated that the bottom wrinkle brow expression was significantly more right-biased than the bottom suck on straw [$t(39) = -12.75$, $p < .001$] expression. Post hoc t-tests with a Bonferroni correction also revealed that the bottom wrinkle brow expression was significantly more right-biased than both the top suck on straw [$t(39) = -12.82$, $p < .006$] and top wrinkle brow [$t(39) = -5.59$, $p < .006$] expressions. The bottom suck on straw expression displayed a significantly greater left-sided asymmetry than both the top suck on straw [$t(39) = 6.12$, $p < .006$] and top wrinkle brow [$t(39) = 3.85$, $p < .006$] expressions. There was not a significant difference in facedness between the top wrinkle brow and top suck on straw expressions.

TABLE 13

Adjusted Asymmetry Scores

	WRINKLE BROW				SUCK ON STRAW		
	M	sd	L/R		M	sd	L/R
TOP	-0.03	(0.18)	13/27	a	-0.04	(0.05)	7/33 b
BOTTOM	-0.19	(0.06)	1/39	c	0.08	(0.12)	33/7 d

Post hoc summary: a>c***, b>c***, d>a,b,c***, a=b

\+ - p< .10   * - p< .05   ** - p< .01   *** - p< .006

The prior analyses measured differences in the asymmetry scores between two factors. As discussed previously, a significant difference in the asymmetry scores between two factors does not guarantee that any individual factor is significantly asymmetrical. Thus, to determine whether an individual expression was asymmetrical, two a priori one sample t-tests were conducted for the lower portion of the face and two post hoc one sample t-tests with a Bonferroni correction were conducted for the upper portion of the face.

The results indicated that both expressions were asymmetrical in the lower face, however, the two expressions differed in the direction of the lower face bias. For example, the asymmetry was right-sided for the wrinkle brow expression [t(39) = -20.41, p< .001] and left-sided for the suck on straw expression [t(39) = 4.08, p< .001]. In the

upper face, a right-sided bias was found for the suck on straw expression [t(39) = -4.71, p< .006].

In summary, the results of the additional nonemotional analyses were somewhat consistent with the previous nonemotional data, particularly in the upper face. Although the adjusted asymmetry scores indicated that only the suck on straw expression displayed a significant right-sided asymmetry in the upper face, the adjusted entropy scores revealed a significant right-sided asymmetry for both expressions. Taken together, the results of the additional nonemotional analyses in the upper face are consistent with both the other nonemotional and emotional analyses.

In the lower face, the results from the analyses on the suck on straw and wrinkle brow expressions were inconsistent with the analyses of the other nonemotional expressions. Whereas, the two emotional homlogues were symmetrical in the lower face, the additional nonemotional expressions displayed asymmetries that favored the left and right side of the face. Thus, the nonemotional expressions as a group did not display a meaningful pattern, nor did they mimic the results of the emotional expressions.

Association between Emotional and Nonemotional Expressions

In their study, Borod and Koff (1983) found significant left-sided biases for nonemotional expressions. They suggested, however, that the biases of the nonemotional expressions were not significantly correlated with those of

the emotional expressions, and therefore, one could interpret the asymmetries of the emotional expressions as evidence of an hemispheric specialization for emotion. To test whether emotional and nonemotional expressions were associated, Pearson correlations of the asymmetry scores were conducted. The results indicated some significant correlations in asymmetry. The show teeth expression was correlated with the emotional expressions in the lower face and the lower eyebrows expression was correlated with the angry expression. (See Table 14 for correlations).

TABLE 14

Correlations - Emotional and Nonemotional Expressions

	Angry		Happy	
	Bottom	Top	Bottom	Top
Lower Eyebrows	-.1286	.5739***	.0524	.1286
Show Teeth	.3502*	.2589	.6390***	.2015
Wrinkle Brow	-.0712	.1754	.1829	.0790
Suck on Straw	.1108	.2450	.0902	.1015

+ - p<.10   * - p<.05   ** - p<.01   *** - p<.001

Non-parametric Test of Laterality

In the preceding analyses, parametric tests were conducted. Prior research, however, has often utilized forced choice procedures which creates nominal data. In the

current study, the subjective ratings were conducted with a
forced choice format. For the purpose of comparison, the
digitized data for each expression by each subject were
classified as either left-biased or right-biased. All
expressions with a positive asymmetry score were categorized
as left-sided and all expressions with a negative asymmetry
score were categorized as right-sided.

Binomial tests were conducted with the nominal data and
the results were generally consistent with the parametric
analyses. For example, the binomial tests indicated that a
significant portion of the subjects were right-biased in the
upper face for all of the expressions. In the lower face,
two of three negative emotional expressions (angry and fear)
displayed a significant left-sided bias. The third negative
expression (sad) was not significantly asymmetrical;
however, sixty percent of the subjects did display a left-
sided bias during this expression. The only positive
expression was found to have a trend for a right-sided
asymmetry. Of the nonemotional expressions, there was no
clear pattern of asymmetry. Two of the four expressions
were symmetrical (lower eyebrows and show teeth), while the
other two expressions (suck on straw and wrinkle brow)
differed in the direction of the expressed asymmetry. (See
Table 15 for tabulation of laterality).

TABLE 15

Total # of Subjects Categorized Left or Right Biased

	Lower		Upper	
	Left	Right	Left	Right
Angry	37***	3	4	36***
Happy	14	26+	4	36***
Sad	24	16	4	36***
Fear	32***	8	9	31***
Lower Eyebrows	15	25	11	29**
Show Teeth	19	21	5	35***
Wrinkle Brow	1	39***	13	27*
Suck on Straw	33***	7	7	33***

+ - p<.10   * - p<.05   ** - p<.01   *** - p<.001

Subjective Ratings of Expressive Asymmetries

Prior research has found evidence of expressive facial asymmetries using the judgment of subjective raters. Consequently, 15 raters were given a forced choice task in which they were asked to choose the most intense expression. A pair of a right and left-sided composite pictures were constructed from digitized images for each expression produced by each subject. Duplicates of 10% of the composites were introduced to assess the stability of the impressionistic ratings. The results indicated that the intrarater reliability ranged from a low of 54% (near chance) to a high of 79% with an average of 68%. The

intrarater reliability varied by expression: angry (85%),
happy (57%), lower eyebrows (58%), show teeth (67%), suck
straw (65%) and wrinkle brow (75%).

To determine whether the consensus for each expression
suggested an expressive asymmetry, a set of six binomial
tests were performed on the nominal data. Results revealed
a significant right-sided bias for the suck on straw
condition [b(left chosen/total) = .30, p= .018]. No other
expressions were found to be significantly asymmetrical.
(See Table 16 for forced-choice impressionistic ratings).

TABLE 16

Subjective Selection of Left Composite

b

	b
Angry	.375
Happy	.625
Lower Eyebrows	.525
Show Teeth	.500
Wrinkle Brow	.475
Suck on Straw	.300*

* - p<.05

Effect of Lighting Bias on Subjective Ratings

As noted previously, a lighting bias was found to
correlate with the digitized data. To assess the impact of
the lighting bias on the impressionistic ratings, a baseline

measure of mean pixel intensity for each side of the face was calculated prior to the production of the facial expression. The difference in mean pixel intensities between each side of the face for each subject was then correlated with the subjective ratings of each expression for each subject. There were no significant associations. (See Table 17 for correlation between lighting bias and impressionistic ratings).

TABLE 17

Correlation - Lighting Bias and Subjective Ratings

	r
Angry	.038
Happy	-.138
Lower Eyebrows	.155
Show Teeth	-.176
Wrinkle Brow	-.288+
Suck on Straw	.040
	+ - $p<.10$

Agreement between Digitized Data and Subjective Ratings

It has been proposed that human raters make their decisions about expressivity based upon facial movement. Some researchers have specifically instructed raters to use facial movement to make their ratings of expressive intensity (Borod and Caron, 1980; Moreno et al., 1988).

Consequently, a quantitative method of assessment that is highly sensitive to movement would be expected to correlate with impressionistic ratings. An exploration of this issue is the fourth question of interest. To test the level of agreement between the impressionistic ratings and digitized analysis, the two methods were compared as to how they classified each expression (left-sided vs. right-sided). Binomial tests were conducted with the nominal data and there was little evidence of an association. A significant degree of agreement was found only for the angry expression (b= .675, p=.04). (See Table 18 for agreement levels).

TABLE 18

Agreement - Subjective Ratings and Digitized Data

	b
Angry	.675*
Happy	.400
Lower Eyebrows	.600
Show Teeth	.625
Wrinkle Brow	.525
Suck on Straw	.550

* - p<.05

Vertical Focus of Subjective Ratings

The fifth question asked whether raters rely more upon the bottom or top portion of the face while making their

judgments of expressive intensity. Prior research indicates that human raters are able to assess the intensity of a happy expression based on lower face movement alone (Leonard et al, 1991). The question remains as to whether human perception is influenced moreso by the upper or lower portions of the face.

Because the subjective ratings produced nominal data, a set of six binomial tests were conducted to determine the level of agreement between the bottom portion of the digitized images and the subjective ratings of the composite whole faces. A second set of six binomial tests were also conducted to test the association between the top part of the digitized images and the subjective ratings of the composite whole faces.

The results indicated that the subjective ratings displayed somewhat greater agreement with the top portion of the digitized images. The agreement between the subjective ratings and the top portion of the digitized image reached significance for the angry (b= .675, p=.04) and suck on straw (b= .675, p= .04) expressions. There were no significant associations between the bottom portion of the digitized image and the subjective ratings of any of the six expressions. (See Table 19 for agreement between subjective ratings and the digital analysis of the top and bottom of the face).

TABLE 19

Agreement by Portion of Face - Subjective vs. Digitized

	$\underline{b}$ (Top)	$\underline{b}$ (Bottom)
Angry	.675*	.400
Happy	.625	.575
Lower Eyebrows	.550	.550
Show Teeth	.575	.575
Wrinkle Brow	.450	.550
Suck on Straw	.675*	.450

* - $p<.05$

Effect of Training on Subjective Ratings

Finally, prior research has generally utilized either a large number of raters or a few trained raters to make intensity ratings. The sixth question of interest asked whether training raters improved their agreement level with the digitized analysis. Consequently, we examined the consensus selections of 3 of the 15 raters who had been trained in detecting facial expressions. The intrarater reliability for the three trained raters were 67%, 79% and 79%. The interrater agreement for the three pairs of trained raters were 72%, 70% and 70%.

To determine whether training increased the likelihood of detecting expressive asymmetries, a set of six binomial tests were conducted on the nominal data produced by the trained raters. The results revealed a significant right-

sided bias for the suck on straw expression (b= .325, p=.04) which was consistent with the results of the untrained raters. There was a trend toward the left side for the show teeth expression (b= .65, p= .082). No other expression approached or reached a significant degree of asymmetry. Thus, training appeared to have no meaningful effect on the judgments of expressive asymmetry. (See Table 20 for impressionistic ratings by trained raters).

TABLE 20

Subjective Selection of Left Composite (Trained Raters)

	b
Angry	.500
Happy	.550
Lower Eyebrows	.500
Show Teeth	.650+
Wrinkle Brow	.450
Suck on Straw	.325*

+ - p<.10   * - p<.05

To directly address the sixth question (whether training increases the agreement level with the digitized data), a set of six binomial tests were conducted to determine the association between nominal data of the digitized analysis and the consensus of the trained raters. The results indicated a significant agreement level only for

the lower eyebrow expression (b= .675, p= .04). There were no significant associations between the digitized data and the selections of the untrained raters. In summary, there was little evidence of improved agreement as a result of training. (See Table 21 for agreement level between digitized data and impressionistic ratings).

TABLE 21

Effect of Training on Agreement with Digitized Data

	b (Trained)	b (Untrained)
Angry	.600	.625
Happy	.475	.450
Lower Eyebrows	.675*	.600
Show Teeth	.525	.525
Wrinkle Brow	.500	.450
Suck on Straw	.525	.500

+ - p<.10   * - p<.05

DISCUSSION

For the past three decades, there has been an intensive investigation of a possible hemispheric specialization in the production of emotion. In general, prior researchers have utilized an indirect measure to make inferences about hemispheric activity and a similar approach was used in the current study. This indirect measure is based upon asymmetries in voluntary facial expressions. A long line of research has utilized this approach and there are three major hypotheses relevant to hemispheric specialization and facial asymmetries (Chaurasia and Goswami, 1975; Sackeim et al., 1978, Campbell, 1978; Sirota and Schwartz, 1982; Borod et al., 1983; Hager and Ekman, 1985; Wylie and Goodale, 1988; Moreno et al., 1990). They are the RH hypothesis, the Valence hypothesis and the Facial Mobility hypothesis. The experiment was designed such that the major hypotheses would be dissociable.

Normal male volunteers produced six facial expressions (two emotional and four nonemotional) which were analyzed for facial asymmetries. An additional two emotional expressions were also analyzed. Results most consistent with the RH hypothesis would include left-sided asymmetries for the emotional expressions and no asymmetries for the

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nonemotional expressions. Borod and Koff (1983) have argued
that asymmetries for nonemotional expressions are not
necessarily incongruent with the RH hypothesis if
asymmetries for emotional and nonemotional expressions are
uncorrelated. Results best supporting the <u>Valence
hypothesis</u> would involve a left-sided bias for negative
emotional expressions and a right-sided bias for positive
emotions. Again, there should be no asymmetries for
nonemotional expressions, or the asymmetries should be
uncorrelated with emotional face expressions (if the
argument of Borod and Koff is accepted). Finally, according
to the <u>Facial Mobility hypothesis</u>, identical patterns of
asymmetry would be expected for both emotional and
nonemotional expressions.

To examine these hypotheses, a relatively new technique
involving digitized analysis was employed to index
expressive asymmetries. In utilizing this approach, two
assumptions were made. First, it was assumed that changes
in the surface lighting of the face as it moved during the
course of an expression reflected the mobility of the face.
Specifically, changes in pixel intensities of digitized
images were thought to be the consequence of facial
movement. The second assumption is that mobility is a
direct index of overall expressivity (Borod et al., 1981;
Moreno et al., 1990). In line with these assumptions have
been the observations of Leonard et al (1991) who found that

subjective ratings of emotional expressivity corresponded to the period during which the maximum amount of change in pixel intensity occurred.

Digitized analysis has the potential to be both a sensitive and an objective measure. A recent study of rhesus monkeys supports the efficacy of the digitized approach. Hauser (1993) obtained recordings of up to 19 free-ranging monkeys making facial expressions. The expressions were associated with fear, copulation and aggression. The emotional expressions were initiated quicker and were more intense on the left side of the face. Subjective ratings by human judges were consistent with the digitized data. Hauser interpreted his results as support for the RH hypothesis.

The Hauser (1993) study differs from the current study in that expressivity was determined by the number of skin folds and the height of the mouth, rather than changes in pixel intensity. Also, the subjects were monkeys and the expressions were spontaneous. The relevance of spontaneous expressions for testing hemispheric influence has been questioned based upon innervation patterns. The current study further tests the efficacy of the digitized method, especially as it applies to human facial expression.

Preliminary data using this technique were obtained during the course of a pilot study with 20 normal subjects (10 males, 10 females). For males, more mobility occurred

on the left (vs. right) side of the face during the expression of negative emotions. No systematic asymmetries were observed for females (Richardson et al., 1994). Although these data suggest that hemiface asymmetries may be identified using digitized analysis of video signals, larger sample sizes are clearly necessary in order to establish reliability of the obtained findings. Thus, the present study was conducted with 40 males.

The primary questions of interest were designed to examine methodological issues associated with the digitized approach to measuring hemiface activity and to evaluate the obtained data in the context of several laterality models regarding the basis of expressive face asymmetries. The first series of questions asked whether emotional expressions are asymmetrical, if the valence of the emotional expression impacts the direction of the asymmetry and whether similar asymmetries also occur for "nonemotional" expressions. For example, the RH hypothesis predicts that the left hemiface is more active during all emotions. The Valence hypothesis predicts that the left hemiface is more active during negative emotions and the right hemiface is more active during positive emotional expressions. The more general "peripheral" view predicts that both emotional and nonemotional expressions should display similar patterns of asymmetry. According to this hypothesis, one side of the face may overall be more mobile

because it has greater muscle mass or better peripheral innervation (Facial Mobility hypothesis). Any resultant asymmetries have little, if anything to do with a hypothesized hemispheric specialization for emotion.

Asymmetries in the Lower Face: Valence Dependent

A major finding of this study was clear evidence for asymmetries in the lower face during emotional expressions. Here, the angry, sad and fear expressions were all left-biased. The asymmetry for sad expressions was somewhat weaker and possibly due to the tendency of many subjects to generate less movement in the lower face during a sad expression. In contrast to this left bias for negative emotions, there was an opposite effect for the only "positive" emotion used in this study. The happy expression, while only approaching significance, tended to result in greater mobility over the right lower quadrant in the face (p< .10). This trend for smile expressions to display a right lower quadrant bias is certainly more in line with the predictions of the Valence hypothesis than the RH hypothesis.

Somewhat different findings occurred with the four nonemotional expressions. Of these expressions, no clear pattern of asymmetry emerged. The two emotional homologues (lower eyebrows and show teeth) were symmetric across the lower left and right quadrants, while the additional nonemotional expressions (wrinkle brow and suck on straw)

were asymmetric in opposite directions. The wrinkle brow expression showed a significant bias that reflected more mobility in the lower right quadrant. Why this particular expression should result in a lower right asymmetry is unclear, particularly since it is carried primarily by the corrugator and frontalis muscles of the 'upper face' (Hiatt and Gartner, 1987). In contrast, the suck on straw expression requires a substantial level of lower face movement, and interestingly, the bias for this expression was predominately left-sided. Thus, two of the nonemotional expressions were symmetrical, one was left-sided and one was right-sided. When considered along side the findings from the emotional expressions, these data undermine the notion that a side of the lower face is overall more mobile or distinctive due to purely structural or peripheral factors.

Taken together, the valence-related emotion asymmetries in the lower face are more consistent with the Valence versus RH hypothesis. Further, because the emotional homologue expressions were symmetrical in the extent of their mobility, this further reinforces a Valence account. As previously discussed there are at least two different versions of the Valence hypothesis: the traditional view and the approach/avoidance account (Davidson, 1993). The traditional view proposes that left-right differences are based on the emotional valence of the expression, such that negative emotions are left-biased while positive emotions

are right-biased. More recent variations of the Valence hypothesis have proposed that the distinction is based upon an approach-avoidance measure, rather than a positive-negative dimension (Davidson, 1993). Accordingly, sad and fear would be considered avoidance emotions, and therefore, a left-sided bias would be predicted for them. A right-sided bias would be expected for angry and happy because they would be considered approach emotions. Given the definite left-sided bias of the angry expression, the results of this study are more compatible with the traditional view of the Valence hypothesis.

The finding of support for the Valence hypothesis is somewhat inconsistent with prior research on expressive asymmetries. In general, previous findings have been more compatible with a RH hypothesis (Campbell, 1978; Borod et al., 1981; Heller and Levy, 1981; Borod and Koff, 1983; Dopson et al., 1984; Borod et al., 1988; Moreno et al., 1990). Only a few studies have been mildly consistent with the Valence hypothesis (Sackeim et al., 1978; Campbell, 1979; Borod et al., 1983). The reason for the discrepancy between the current study and the majority of prior research is unclear.

A possible answer may involve the study of Mandal, Asthana and Pandey (1995) who addressed the issue of laterality in a unique manner. Instead of using the intensity of the expression as a dependent variable, they

included it as one of the independent variables.
Consequently, they found that hemiface biases were dependent
upon the intensity of the expression. Sad and happy
expressions were both biased to the left side of the face
for mild and intermediate intensities. For the more intense
expressions of grief and ecstacy, the face displayed a
right-sided asymmetry. They concluded that the RH
hemisphere was generally involved in emotional expression,
but that the left hemisphere is more dominant, and at times,
supersedes the right hemisphere during emotional
expressions.

If their suppositions are accurate, it may explain some
of the results that have appeared mildly to support the
Valence hypothesis. As discussed, most of the prior studies
on expressive asymmetries have discovered a left-sided bias
during negative and positive expressions. A few studies
have reported a symmetrical pattern for the happy expression
and a left-sided bias for negative expressions. In the
current study, a right-sided lower face asymmetry for the
happy expression approached significance. Why negative
expressions are more consistently left-biased has puzzled
researchers. It may be that subjects are less willing to
express negative emotions intensely, and therefore, these
expressions are more strongly left-biased. Indeed, there is
evidence indicating that some subjects resist expressing
negative emotions.

Alford (1983) found that males were more left-biased in their facial expressions. He posited that this was a result of habitual concealment of certain negative emotions. In support of his view, he demonstrated that females who habitually concealed emotions also tended to display greater left-sided biases. Ekman et al. (1981) reported that children often have difficulty intentionally producing anger, suggesting a discomfort with this negative expression. Furthermore, the digitized data in this study indicated that the happy expression was more active than the negative expressions. Thus, if subjects are less likely to express negative emotions intensely, then according to the results of Mandal et al. (1995), these expressions are more likely to be left-biased. The results of the digitized analysis of the lower face are consistent with this view.

Although many studies of emotional expression are consistent with the RH hypothesis, there is evidence to the contrary. A study of split-brain patients by Gazzaniga and Smylie (1990) contradicted the proposed right hemisphere specialization for emotional production. Indeed, the results indicated that the left hemisphere plays a more prominent role. In their study, three subjects were given verbal commands to pose a smile. The commands were directed to each hemisphere at different times. The authors reported that at least two of the three subjects had significant language comprehension with their right hemisphere. In

addition to verbal commands, two of the three subjects were also shown sad and happy expressions that they were instructed to mimic. Subjects were unable to perform the expressions when the commands or stimuli were presented to the right hemisphere. When presented to the left hemisphere, however, subjects were able to pose the appropriate expressions. Furthermore, when nonemotional expressions were requested (wink, blow), both hemispheres were able to initiate the necessary facial movements. Based on these findings, the right hemisphere does not appear to be specialized for the production of emotion. Because of the right brain's failure to mimic the sad face, the results of this study are inconsistent with both the RH and Valence hypotheses.

On the other hand, there is a population concern with this study. According to the authors, prior testing indicated that the subjects belong to a rare group of people who are able to comprehend language in the right hemisphere. In addition, the subjects have an extensive history of seizures and other neurological signs dating back to childhood. Perhaps, the organization of the brain for these patients is significantly different from the population at large. Therefore, the findings from this study may not be generalizable.

The data from the mimicked expressions indicate that these subjects may, indeed, be atypical. For example,

Gazzaniga and Smylie (1990) reported that the left hemisphere was able to initiate expressions when given a picture to imitate. These results are inconsistent with the findings from Richardson et al. (1992). In their study, the voluntary expressions of RHD and LHD patients were affected depending upon the channel of presentation. RHD patients were specifically impaired when subjects were given photographs of facial expressions that they were to mimic. The intact left hemisphere appeared unable to process the task demand for production. Taken together, the subjects in the Gazzaniga and Smylie (1990) study may not reflect the hemispheric makeup of the normal population.

In sum, the digitized data of the lower face are, on the surface, more compatible with the Valence hypothesis while prior research has tended to be more supportive of the RH hypothesis. The findings of Mandal et al. (1995) indicate that the occasional support for the Valence hypothesis may be an artifact of certain subjects being more willing to express positive emotion intensely. They proposed that the right hemisphere was specialized for emotional production, which was sometimes superseded by the left hemisphere due to its role as the dominant hemisphere. Research by Gazzaniga and Smylie (1990) on split brain patients contradicts both emotion based hypotheses; however, concerns regarding the subject sample call into question the generalizability of their study.

Asymmetries in the Upper Face: Right Upper Bias

Due to the bilateral innervation of muscles in the upper face by cortico-motor efferents from the two hemispheres (Kuypers, 1958; Crosby and DeJonge, 1963; Rinn, 1984), no clear cut predictions were made for the presence of lateral asymmetries in the upper face by either of the hemisphere-emotion models. According to both the RH hypothesis and the Valence hypothesis, emotion based asymmetries in expressivity should occur in the lower portion of the face (due to the contralateral neuroanatomical connectivity), but would not be predicted for the upper face. The upper face should be more symmetric for emotional expressions.

The results were inconsistent with this prediction. All four emotional expressions exhibited a significant right-sided bias in the upper face. The expression of happiness, fear, anger and sadness were all associated with greater mobility in the right versus left side of the upper face. Similarly, a right-sided bias was also unequivocally present for three of the four nonemotional expressions (lower eyebrows, show teeth, suck on straw). The data derived from the wrinkle brow expression were ambiguous in that the asymmetry score reflected equivalent mobility across the two sides of the face, whereas the nonparametric analysis suggested a right-sided bias.

In sum, the combined results rather decisively point to the presence of greater mobility across the right versus left sides of the upper face, regardless of whether the facial expression is emotional or nonemotional. Because the upper face is bilaterally innervated, this upper face mobility difference is not easily interpreted along the lines of a hemispheric advantage. Thus, an upper face bias suggests that other factors must have played a role in generating their occurrence.

It has been proposed that there may be hard or soft tissue differences that favor the right or left side of the face (Ekman, 1980; Nelson and Horowitz, 1980; Koff, Borod and White, 1981). Structural asymmetries may include the upper facial region. For example, if one side of the face is bigger, the expression may appear more intense due to the greater distances available for movement (Borod and Koff, 1990). On the other hand, the smaller side of the face may appear more intense because any expression would be proportionately larger (Nelson and Horowitz, 1980). Regardless of how facial anatomy impacts the appearance of an expression, structural differences may create an illusion of expressive asymmetries.

Throughout this past century, scientists representing a range of disciplines have explored the question of structural asymmetries. The evidence regarding facial asymmetries is somewhat mixed depending upon the nature of

the tissue (hard or soft), the age of the subjects (children, adolescents or adults), the region of the face (upper, lower or middle) and the ethnic group studied. Different methods of measurement have been utilized depending upon the tissue of interest. For the study of hard tissue differences, researchers have either measured human skulls directly (Woo, 1931; Pearson and Woo, 1935) or employed radiographic techniques (Letzer and Kronman, 1967; Vig and Hewit, 1975; Chebib and Chamma, 1981; Melnick, 1992). Results have generally, varied by age, ethnicity and region of the face.

For example, Woo (1931) in his study of 800 ancient Egyptian skulls found that the frontal bone was larger on the right side and the malar bone was larger on the left side. A follow-up study of 14 different ethnic groups did not reveal any consistent differences in the size of facial bones (Woo, 1937). Applying modern statistical techniques to Harrower's study (1928) of the Hylam (Asian), Sackeim (1985) reported significant differences in the widths and heights of the orbital cavities. A horizontal bias was found for the right orbital cavity and a vertical advantage was found for the left orbital cavity.

Radiographic studies have also been generally inconsistent. Several investigations indicated right-sided asymmetries (Melnick, 1992), particularly in the mid face region (Harvold, 1954; Shah and Joshi, 1978), while other

studies suggested either left-sided biases (Letzer and
Kronman, 1967; Vig and Hewitt, 1975; Chebib & Chamma, 1981)
or no significant asymmetries (Posen, 1958; Peck, Peck and
Kataja, 1991). According to the Melnick (1992) study,
younger children initially displayed a left-sided structural
bias which became increasingly right-sided with age. This
shift in facial asymmetry may resolve some of the previous
discrepancies. For example, two of the three studies
indicating a left-sided bias included only children as their
subjects (Letzer and Kronman, 1967; Vig and Hewitt, 1975).
Furthermore, evidence supporting the right-sided bias has
been demonstrated with older adolescent or adult subjects
(Harvold, 1954; Shah and Joshi, 1979; Melnick, 1992).

Taken together, neither the direct measurement of human
skulls nor radiographic techniques reveal a clear and
unequivocal pattern of facial asymmetries. Nonetheless,
there are more studies suggesting that the right side of the
face is larger, particularly for adults. Of these studies,
the asymmetrical structures were generally located in the
mid to lower portions of the face. Consequently, it would
be incorrect to assume that expressive asymmetries in the
upper face were the result of hard tissue differences.

Similarly, the research on soft tissue suggests no
consistent pattern of asymmetry, regardless of the technique
employed. Measurements of facial areas have been calculated
from photographs, stereophotograms, computed tomography and

actual faces (cadavers and living subjects). Several studies were notable for the degree of facial symmetry of the subjects (Sutton, 1969; Burke, 1971; Sackeim and Gur, 1980; Sackeim et al., 1984, Ferrario, Sforza, Miani and Serrao, 1993). The rest of the studies suggested either a larger right hemiface (Nelson & Horowitz, 1980; Ferrario, Sforza, Poggio and Tartaglia, 1994; Ferrario, Sforza, Miani and Serrao, 1995) or discrepancies depending on the area of the face measured (Farkas and Cheung, 1981; Pirttiniemi, Raustia, Kantomaa and Pyhtinen, 1991; Ras, Habets, van Ginkle and Prahl-Andersen, 1994, 1995). Most of these studies concentrated their measurements in the lower to mid face region. Of those that included an evaluation of the upper face (Burke, 1971; Sackeim and Gur, 1980; Farkas and Cheung 1981; Sackeim et al., 1984; Ferrario et al., 1994; Ras et al., 1994, 1995), there was no clear and consistent evidence of facial asymmetry.

For example, Farkus and Cheung (1981) examined multiple facial markers of children and late adolescents. Their results indicated that of the 18-year-olds, the distance between the nasion and tragus was significantly greater on the left side. Ras et al. (1994, 1995) measured the face three-dimensionally and reported a left-sided bias in the transverse plane and a right-sided bias in the sagittal plane. Because the facial features were not analyzed individually, it was unclear how much the upper face

contributed to the asymmetries. Ferrario et al. (1994) also utilized a three-dimensional analysis and reported a right-sided bias in the upper half of the face. These results are somewhat ambiguous because several middle face features were included in the upper face region. The remainder of the studies suggested no significant soft tissue differences in the upper face (Burke, 1971; Sackeim and Gur, 1980; Sackeim et al., 1984; Ferrario et al., 1995). Thus, taken together, expressive asymmetries in the upper face appear to be unrelated to soft (fat, muscle) tissue differences.

There are, however, other elements of soft tissue which may generate expressive asymmetries. For example, neural tissue may be unevenly distributed across the upper face. If the left or right side of the face receives superior innervation, facial movement is likely to be asymmetrical. Before exploring this question, a general review of facial neuroanatomy is in order.

Research indicates that there are two major neural pathways associated with facial expressions. Each pathway originates in different parts of the brain and is associated with distinct types of facial expressions. For example, the extrapyramidal fibers are associated with spontaneous or involuntary expressions and the relevant neural impulses are initiated from the subcortical regions of the brain. The corticobulbar tract is identified with posed or voluntary expressions and its origins are traced to the motor cortex

(Monrad-Krohn, 1924; Kuypers, 1958; Crosby and DeJonge, 1963; Kahn, 1964). Because only posed expressions were elicited in this study, the innervation patterns associated with the motor cortex are most relevant.

Neural impulses initiated in the motor cortex descend along the corticobulbar pathway and travel through the internal capsule. Eventually, the signals reach the facial nucleus in the pons region of the brainstem. Along the corticobulbar tract, there are both direct and indirect pathways. The indirect pathways first synapse upon the interneurons in the reticular formation which then bilaterally innervate the dorsomedial and dorsolateral portions of the facial nucleus. The bilateral innervation of the upper face is a consequence of its connection to these sections of the facial nucleus. The direct pathways, on the other hand, travel to the more ventral portion of the facial nucleus and innervate it in a contralateral manner. The predominately contralateral innervation of the lower face is tied to its input from the ventrolateral portion of the facial nucleus (Kuypers, 1958; Crosby and DeJonge, 1963; Rinn, 1984).

In the upper face, there are two major branches of the facial nerve. The first is the zygomatic branch which innervates two pairs of muscles: the corrugator and the orbicularis oculi. The two corrugators are located above each eye and produce vertical wrinkles between the eyebrows.

The two orbicularis oculi encircle each eye which they open
and close. The second branch of the facial nerve is the
temporal. The muscles it innervates include the frontalis,
temperoparietalis, auricularis anterior & superior. The
temporal branch also contributes to the innervation of the
corrugator and orbicularis oculi. The temperoparietalis,
auricularis anterior and auricularis superior are all
muscles which are located near each ear and are involved in
ear movements. The frontalis muscle is a single muscle that
extends from the scalp to the eyebrows. It produces
wrinkles in the forehead and raises the eyebrows. Finally,
portions of the procerus muscle (along the bridge of the
nose) extend into the upper face, although its innervation
is of lower face origin (Hiatt and Gartner, 1987; Fatah,
1991).

These are the muscles that contribute to upper face
movement. Neuroanatomy indicates that these muscles are
bilaterally innervated, and therefore, receive input from
both the contralateral and ipsilateral hemispheres (Kuypers,
1958; Crosby and DeJonge, 1963; Kahn, 1964). Consequently,
differences in hemispheric activity should not produce
expressive asymmetries in the upper face. As previously
entertained, however, expressive biases might be associated
with peripheral innervation patterns. Perhaps, neural
configurations favor one side of the face creating an
asymmetry in movement potential.

While so much is known about neural associations with muscle groups, the lateral bias of facial nerves has received only limited research. In one study, Fatah (1991) found that the innervation patterns varied noticeably on each side of the upper face. He did not explore the issue further leaving the question of neural asymmetry unanswered. Furthermore, a literature review suggests that nobody has undertaken a systematic study to assess the symmetry of upper face innervation. Thus, inferences about innervation asymmetries can only be made from indirect measures. Whether assessed via direct or indirect means, innervation patterns in the upper face are potentially significant in that they may shed light on the expressive asymmetries found in the current study.

The approach based on the electrical output of peripheral neurons following the direct stimulation of the motor system may serve as an indirect gauge. In this technique, the motor system is activated via the motor cortex itself or an accessible point on the corticobulbar tract (Maccabee, Amassian, Cracco, Cracco and Anziska, 1988; Rosler, Hess and Schmid, 1989; Rimpilainen, Eskola, Hakkinen and Karma, 1991). Stimulation has been accomplished through magnetic or electrical means (Schreifer, Mills, Murray and Hess, 1988; Rosler et al., 1989; Oishi and Takasu, 1993). Regardless of the stimulation site or method, the results of these studies consistently suggest a symmetrical level of

neural input in the middle and upper face (Schriefer et al., 1988; Cruccu, Berardelli, Inghilleri and Manfredi, 1990; Rimpilainen et al., 1991).

Nonemotional facial movements provide a second indirect measure of neural activity. As previously discussed, a bias during nonemotional expressions suggests some form of peripheral asymmetry. Clearly, emotional and nonemotional movements in the current study were right-biased across the upper face - a finding that is generally inconsistent with prior research.

For example, Ekman et al. (1981) combined data from the lip and eyebrow movements of 36 children and reported an overall left-sided bias. Campbell (1982) in a task that presumably involved the upper and lower face reported a left-sided bias for 16 subjects pulling their faces up and down. Furthermore, Alford (1983) reported a left-sided advantage for raising the eyebrow for 38 right-handed males. Each of these studies contradicted the right-sided upper face bias found in the current inquiry.

The only prior study suggesting a right-sided upper face bias was conducted by Alford and Alford (1981). Their research indicated that 255 university students preferred winking their right eye. In contrast, Chaurasia and Goswami (1975) found a left-sided bias for 300 Asian Indians in their ability to wrinkle the forehead and wink each eye. Borod et al. (1981) also examined eye facility. They

instructed 42 university students to close each eye

separately. A trend was found favoring the left side of the

face. In the three studies examining eye movement, the

nature of the dependent variable was somewhat different.

For example, Alford and Alford (1981) recorded which eye was

preferred, while the other two studies rated the quality of

the wink. There is evidence that the different assessment

techniques may explain these divergent results. For

example, Borod and Koff (1983) reported differences in

winking facility based on performers and observers.

Although not statistically significant, the results did

indicate that more performers believed their right eye to be

superior and more observers rated the left eye as superior.

With the exception of the Alford and Alford (1981)

inquiry, none of the research on nonemotional expressions is

consistent with the findings of the present study.

Furthermore, there is no clear evidence suggesting

structural variations are correlated with the results of

this study. There are several possible explanations for

these inconsistencies. First, the area of the face

available for the digitized analysis did not include the

whole face. Eliminating the outer edges of the face was

necessary to ensure that each side of the face was equally

represented. Perhaps, a more limited window on the face

alters the effect of facial movement. (A more thorough

discussion of window size is included under methodological

concerns). Second, the digitized analysis is a more objective measurement of facial activity. Nearly all of the studies examining nonemotional movements have utilized subjective ratings. It has been common for the results of other objective approaches to diverge from the research utilizing subjective methods (Sirota and Schwartz, 1982; Hager and Ekman, 1985; Wylie and Goodale, 1988).

Finally, the Facial Mobility hypothesis assumes that there are, in fact, nonemotional expressions. It may be that no facial movement is completely devoid of emotion. Critics might argue that each of the nonemotional expressions in this study contained emotional triggers. The emotion homologues were intentionally designed to produce movement similar to an emotional expression. Perhaps, the mere process of mimicking an emotional movement, elicited the involvement of the emotional production centers.

To counter this possibility, the wrinkle brow and suck on straw expressions were also included since the movements of these expressions did not mimic basic emotional expressions. Perhaps, these expressions were also tainted by an emotional element. Inconsistent with this position, however, is that there was a dissociation in the lower face between the emotional and nonemotional expressions in this study. If a hemispheric specialization for emotion was driving the biases and the nonemotional expressions were, in fact, emotional, one would expect that the "nonemotional"

expressions would have also shown a consistent pattern of asymmetries in the lower face.

Relationship between Digitized Data and Subjective Ratings

A second set of questions addressed in this study dealt with the relationship between the subjective ratings and the digitized data. Although many previous studies have found that the left hemiface is judged by raters to be more emotionally expressive than the right (Sackeim, 1978; Campbell, 1978; Borod and Caron, 1980; Heller and Levy, 1981; Dopson et al., 1984; Moreno et al., 1990), the present study did not. Here, raters were shown pairs of still digitized pictures consisting of a left hemiface composite and a right hemiface composite, both of which were constructed from the final frame of the video segment. When asked to select the more expressive image, the raters did not systematically select the left hemiface. The subjective ratings reflected no evidence of greater expressivity for the left hemiface, even though the digitized data indicated that the lower left hemiface was more mobile during negative expressions. Thus, there was a discrepancy between the subjective ratings and the digitized data. Indeed, when the two approaches were compared as to how they classified each individual expression, there was very little concordance between them. Only the angry expression reached a significant level of agreement.

Because different patterns of facial asymmetry characterized the lower versus upper face, the correspondence was calculated between the whole face subjective ratings and the digitized data from the upper and lower portions of the face. Again, there was no consistent pattern between the whole face subjective ratings and the digitized data for either portion of the face.

A similar discordance was obtained in the initial pilot study with three naive judges and the question was raised as to whether the a lack of expertise or "training" might have played a role in the aberrant findings (Richardson et al., 1994). Prior studies have generally relied on either numerous untrained raters or a small number of highly trained raters. To address the question whether "training" would improve the level of agreement between the subjective ratings and the digitized data, both groups of naive raters and highly trained raters were employed.

In brief, training appeared to have very little effect on the subjective ratings of expressivity. Similar to the naive raters, there was no concordance between the ratings of the trained subjects and the digitized data. Likewise, the trained and naive raters appeared to view intensity of facial expressivity in similar ways. At a basic level, this implies that human adults are uniquely competent at apprising the intensity of social affective signals such as facial expressions, and that training, above and beyond that

experienced during the course of normal development, does not improve or dramatically alter this ability. In fact, normative data derived from tests which assess decoding of nonverbal affective signals such as facial expressions and tone of voice (e.g., Florida Affect Battery) indicate by the age of 10-12 years, children are performing at the level of adults (Voeller, unpublished data). Even at younger ages of five to six years, children display remarkable competency in decoding such signals, and any differences that occur relative to the adult are related to secondary task demands (i.e., increased attentional and working memory demands), rather than true differences in understanding the meaning of affective signals.

In sum, these findings revealed no significant correspondence between the subjective ratings and the digitized data set. Because a vast array of previous neuropsychological studies have generally found that raters view the left hemiface as more expressive than the right (Sackeim et al., 1978, Borod & Caron, 1980, Dopson et al., 1984 and Braun et al., 1988), the failure to replicate is an atypical finding. Consequently, the question arises as to possible methodological factors contributing to the anomalous outcome. Several possible methodological issues are discussed below.

Methodological Issues and the Subjective Ratings

There are several methodological concerns that may have reduced the validity of the subjective ratings in the present study. The first possible problem was a subtle lighting bias which was detected in the digitized analysis. The asymmetry in lighting intensity may have influenced the perceptions of the human raters. However, a statistical analysis of the subjective ratings and the difference in resting pixel intensities (left and right side of the face) revealed no significant correlations. It is, therefore, unlikely that uneven lighting contributed to the atypical results of the subjective ratings.

The second methodological issue involves presentation of the test stimuli. Previous research can be divided into studies which have presented either a static or dynamic image for the impressionistic ratings. In this study, the subjective raters were given a static image from which to make their judgments. The distinction between static and dynamic may be significant because they may tap different visual systems (Trevarthen, 1968; Paillard, 1980; Blouin, Teasdale, Bard and Fleury, 1993).

Vision research suggests that there is one system which processes slow moving (or stationary) stimuli and another which processes fast moving stimuli (Trevarthen, 1968; Palliard, 1980; Blouin et al., 1993). Consistent with the two system proposal is that the central portion of the

retina (the fovea) is specialized for processing the details and position of an image, whereas the peripheral parts of the retina are more sensitive to changes in movement and acceleration (Trevarthen, 1968; Palliard, Jordan and Brouchon, 1981; Blouin et al., 1990). Furthermore, research indicates that the cells of different areas of the retina and the lateral geniculate nucleus are physiologically and functionally distinct. In the retina, the cells associated with the periphery have been classified as y cells and those associated with the fovea as x cells (Palliard et al., 1981; Blouin et al., 1993).

It may be that different visual systems are activated depending upon the method of presentation, but prior research does not suggest any discrepancy between the ratings of static and dynamic images. For example, many researchers utilizing static images have reported some evidence of a left-sided bias for posed expressions (Sackeim, 1978; Campbell, 1978; Borod and Caron, 1980; Dopson et al., 1984). Subjective ratings of video images have also tended to indicate a left-sided bias (Borod et al., 1981; Borod et al., 1983; Moreno et al., 1990).

Although static versus dynamic presentation seems unlikely to explain some of the discrepancies associated with previous research, the incongruity between the digitized analysis and the subjective ratings of this study may be attributable to a static versus dynamic approach.

For example, a dynamic image might be affected by baseline differences, whereas a static image would not. Thus, if there were initial asymmetries in the face at the beginning of the expression, one side might have a greater area available for movement.

Consistent with this view is that neutral expressions have been found to appear sadder on the left side of the face (Campbell, 1978). There may be a subtle downward curl of the lip at rest. Consequently, the expressions in this study may have appeared more symmetrical at their peak, yet one side may have moved more to reach the peak of the expression. If so, the digitized analysis would have been sensitive to the greater movement, while the subjective ratings would not have been. This may be a plausible explanation as to the divergent results of the digitized analysis and the subjective ratings, but it does not explain the discrepancies between the subjective ratings and prior research.

The third methodological concern was the quality of the pictures used for the ratings. The quality of the pictures may have been diminished by the size of the pictures, the area of the face shown and the manner in which they were produced. The first issue is related to the manner of production. For static images, prior research has relied upon developed still photographs or slides. In the present study, the test stimuli were printed copies of the digitized

images. Each printed image appeared somewhat similar to a photograph of a television picture. Consequently, the clarity was reduced and the subtleties of the expressions may have been lost.

Another issue of picture quality involves the amount of the face presented. In the current study, the edges of the face were removed and unavailable for the subjective ratings. In contrast, many other studies reported that all parts of the face were visible for their raters (Sackeim, 1978; Campbell, 1978; Heller and Levy, 1981; Moreno et al., 1990). In a few studies, raters were directed to attend to the lower half of the face, but the whole face was presented (Borod and Caron, 1980; Borod et al., 1981; Braun et al., 1990). Some studies did not indicate how much of the face was shown and whether the edges of the face were excluded (Cacioppo and Petty, 1981; Dopson et al., 1984; Mandal et al., 1995). None of the studies explicitly stated that parts of the face had been eliminated from view.

In the current study only a window of the face was available for the raters. For example, the outer edges of the cheeks were deleted as well as parts of the chin and brow. This was done to produce a precisely symmetrical shape and to avoid the inclusion of the subjects' hair and nonfacial material (neck, shirt and backdrop). Maintaining a symmetrical image ensured the validity of the left-right comparisons in the digital analysis. The boundaries of the

image used in the digital analysis were the same as those in the printed image for the subjective ratings. It was deemed beneficial to include exactly the same area of the face for the digitized analysis and the impressionistic ratings if the two were to be compared.

By removing parts of the face, the potential to generalize from this study may have been diminished. On the other hand, there are advantages. For example, creating symmetrical images for the subjective ratings addresses an early criticism of the research in this area. Nelson and Horowitz (1980) suggested that biases in facial expressions were the artifact of asymmetries in facial widths. They argued that the smaller hemiface would have a greater proportion of the face moving and appear as though it were more expressive. Conversely, the bigger side of the face may appear more expressive due to the greater amount of movable tissue (Borod and Koff, 1990). Either way, the early critique of subjective ratings has been that asymmetries in facial width might create the illusion of expressive asymmetries.

The final concern regarding picture quality pertains to the size of the images. In previous research, enlarged photographs, projected slides or video stills were the stimuli from which the raters made their judgments (Sackeim et al., 1978; Rubin and Rubin, 1980; Borod and Caron; Dopson et al., 1984). In this study, the facial expressions were

displayed on 2.5 by 2.5 inch digitized prints. Perhaps, the small picture size affected the subjective ratings. Critical features that are observable in larger pictures may have been obscure and less helpful in comparing expressivity. Evidence that the size alone was not a major confounding variable is that Campbell (1978, 1979) presented 5 x 4 cm. pictures to her raters and expressive asymmetries were reported.

It is unclear which of these concerns about picture quality accounts for the anomalous findings in this study. Perhaps, it was not one factor alone, but rather a combination that altered the subjective ratings. The possibility exists that had the printed digitized images been a typical size or had the smaller pictures been developed photographs, the results may have been more consistent with previous research. Further study is necessary to address these issues.

CONCLUSION AND FUTURE DIRECTIONS

The current approach utilizing digitized analysis was
capable of detecting expressive asymmetries. The pattern of
revealed asymmetries was different for the upper and lower
face. The lateral biases were consistent with the Facial
Mobility hypothesis in the upper face and the Valence
hypothesis in the lower face. In contrast, the subjective
ratings in the current study indicated that no emotional
expression was asymmetrical. The results of the subjective
ratings were inconsistent with both the digitized analysis
and prior research utilizing human raters. There were
significant methodological weaknesses associated with the
subjective ratings in this study.

In the upper face, nearly all of the expressions were
right-biased. Because the upper face is bilaterally
innervated (Kuypers, 1958; Crosby and DeJonge, 1963; Rinn,
1984), the Valence and RH hypotheses predict that this
facial region is symmetrical during emotional expressions.
The results of the digitized data are inconsistent with
these predictions. The Facial Mobility hypothesis proposes
that peripheral factors may be responsible for expressive
asymmetries, and biases are possible, regardless of
innervation patterns. Consequently, the Facial Mobility

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hypothesis predicts that all expressions should be similarly asymmetrical which is compatible with the findings from the digitized analysis.

For the lower portion of the face, the results appeared to favor an emotion based hypothesis. Nonemotional expressions tended to be more symmetrical, while emotional expressions were generally asymmetrical. This combination is inconsistent with the Facial Mobility hypothesis. For the negative emotional expressions, there was a left-sided bias which was compatible with both the RH hypothesis and the Valence hypothesis. A right-sided trend for the happy expression was consistent with the Valence hypothesis, but inconsistent with the RH hypothesis.

Taken together, none of the hypotheses correspond completely with the data from the digitized analysis. Because the major hypotheses are not mutually exclusive, more than one mechanism may be operating simultaneously. For the lower face, the digitized data is somewhat consistent with the RH hypothesis and most consistent with the Valence hypothesis. The Facial Mobility hypothesis fits well with the digitized data of the upper face.

Evidence Supporting the Valence Hypothesis

The Valence hypothesis assumes that the two cerebral hemispheres are specialized to process different emotions. The right hemisphere is believed to have an advantage for negative emotions and the left hemisphere is thought to be

specialized for positive emotions. A modified version of the Valence hypothesis differentiates emotions along an approach-avoidance axis, rather than a positive-negative dimension (Davidson, 1993). Support for the Valence hypothesis has generally been associated with research involving the experience of emotion, rather than the intentional expression of emotion.

Although past research on the expression of emotion has generally been inconsistent with the Valence hypothesis, the results from the lower face of this study are more compatible with it. First, the direction of the expressive asymmetries, even when not significant, was consistent with the Valence hypothesis. Second, the angry and happy expressions were found to be significantly different in their asymmetry scores. This difference is not only compatible with the Valence hypothesis in general, but also is more consistent with the traditional view of the Valence hypothesis.

Given the historically weak evidence supporting the Valence hypothesis, the inclusion of more positive expressions in the current study would have enhanced the confidence in its results. A limit on the number of positive expressions has been a fundamental problem associated with this line of research, primarily, because there is only one universally accepted basic, positive emotion. Some authors have tested other positive emotions

such as amusement and sexual arousal (Borod and Caron, 1980; Borod and Koff, 1983) and their findings indicate that these different variations are generally consistent with each another and tend to be left-biased. An area of future exploration would be the use of digitized analysis to assess the asymmetries of additional positive expressions.

Evidence Supporting the Right Hemisphere Hypothesis

The RH hypothesis proposes that an emotional processing and production center is located in the right hemisphere. Accordingly, the evaluation of emotional stimuli and the production of emotional signals is thought to be executed primarily in this side of the brain. Stronger support for the RH hypothesis has been associated with the evaluation, rather than the production of emotion. Although there are many studies of emotional expression that are consistent with the RH hypothesis (Campbell, 1978; Borod et al., 1981; Heller and Levy, 1981; Dopson et al., 1984; Moreno et al., 1990), there are others which are not consistent with a hemispheric specialization (Cacioppo and Petty, 1981; Sirota and Schwartz, 1982; Wylie and Goodale, 1988). The studies that have been less supportive of a hemispheric specialization have generally utilized more objective measures of assessment (Sirota and Schwartz, 1982; Hager and Ekman, 1985; Wylie and Goodale, 1988).

The results of the digitized data from the current study also provides mixed support for the RH hypothesis.

Consistent with the RH hypothesis, most of the emotional expressions were biased to the left side of the lower face, while the nonemotional expressions were more symmetrical. Inconsistent, however, is that the happy expression tended to favor the right side of the face - a finding that is on the surface more compatible with the Valence hypothesis. The research of Mandal et al. (1995) and Alford (1983) suggest that the right-sided trend for the happy expression in the current study may have been caused by the intensity difference, rather than the contrast in emotional valence. Additional laterality research comparing the effects of valence, intensity and emotional concealment might address this issue.

Evidence Supporting the Facial Mobility Hypothesis

The Facial Mobility hypothesis proposes that expressive asymmetries are the consequence of peripheral or central advantages that are unrelated to emotion, and therefore, lateral biases will be present for emotional as well as nonemotional expressions. Prior research has indicated some support for the Facial Mobility hypothesis. Nonemotional expressions in both the upper and lower parts of the face have displayed significant left-sided asymmetries (Chaurasia and Goswami, 1975; Ekman et al., 1981; Koff et al., 1981; Borod and Koff, 1983; Alford, 1983). In the current study, the digitized data indicated that there was a right-sided bias in the upper face for nearly every expression. In the

lower face, the patterns of asymmetry were inconsistent between the emotional and nonemotional expressions. Thus, prior research suggests some support for the Facial Mobility hypothesis, yet the direction of the bias was inconsistent with the findings of the present study.

Although the reason for these discrepancies is uncertain, there are some significant differences between the present study and prior research. First, nearly all of the earlier studies relied upon subjective ratings. Second, the ratings from prior research were generally based upon the whole face, while portions of the face (outer cheeks, upper forehead and lower chin) were excluded in the digitized analysis. Insight into this question might have been gained had the subjective ratings in the current study not been so plagued with methodological concerns. Thus, it is unclear whether the directional discrepancy is associated with the digitized approach, window size or the sample of subjects. Future research comparing the digitized approach and subjective ratings would address this question.

Assuming the validity of the Facial Mobility hypothesis, it remains unclear what specific mechanism produces expressive asymmetries. Based on research of spontaneous expressions (Moscovitch and Olds, 1982; Borod et al., 1983; Dopson et al., 1984; Wylie and Goodale, 1988) and data from individual muscle pairs (Schwartz et al., 1979; Hager and Ekman, 1985), there is some evidence that

peripheral factors may be involved. Despite the inferential

evidence suggesting the role of peripheral factors, research

on hard and soft tissue has provided little direct evidence

supporting this claim. Actual peripheral innervation

patterns have not been thoroughly researched at this point.

Perhaps, one side of the face receives greater neural

involvement. Undoubtedly, a systematic study of cadavers or

patients receiving facial surgery is needed to address this

question.

Multiple Factors Contributing to Expressive Biases

Several authors have argued that expressive asymmetries

may be the result of multiple factors (Borod and Koff, 1983;

Hager and Ekman, 1985). For example, a hemispheric

specialization for the production of emotion may contribute

to greater facial activity on one side of the face.

Structural advantages such as greater muscle mass or greater

peripheral innervation may also provide an edge in movement

capacity for a particular hemiface. A structural bias

would, therefore, either accentuate or inhibit the effects

of a hemispheric specialization in emotional production

(Hagar and Ekman, 1985).

The degree in which these factors compete with one

another might vary in the lower and upper regions of the

face. It stands to reason that the greater the level of

bilateral innervation, the smaller the impact of any

purported hemispheric specializations. Based on the

bilateral innervation of the upper face, this region would likely be influenced by peripheral factors. The contralateral innervation of the lower face suggests the possibility of an interaction of central and peripheral elements. Consequently, a divergence in expressive biases may develop between the upper and lower portions of the face. If the input associated with hemispheric differences was greater than and contradictory to the input resulting from asymmetries in peripheral innervation, then the direction of the lower face bias would differ from the upper face bias.

Furthermore, it is possible that elements of the RH hypothesis and the Valence hypothesis are correct. If both hypotheses were operating simultaneously, then negative expressions would be laterally biased and positive expressions would be more symmetrical. Clear asymmetries for negative expressions would occur on the left side of the face because the processes associated with the Valence and RH hypotheses would enhance each others effects. Weak, rather than strong biases for positive expressions would be the result of these two processes counteracting each other. This interpretation is compatible with the findings of this study and a small number of previous investigations.

In sum, the results from the upper and lower portions of the face are compatible with a multiple process explanation. Because the patterns of bias in the lower face

differed between the emotional and nonemotional expressions, peripheral factors alone are an unlikely source for the expressive asymmetries encountered in this study. The mechanisms associated with each of the major hypotheses can account for some of the results, yet individually, they appear unable to explain all of the digitized data. Further research is needed to explore the possibility of multiple processes generating expressive asymmetries.

Methodological Issues and Future Directions

There were some methodological problems associated with the current study which can be adjusted in future studies. The first concern involved a bias in lighting. The right side of the face often received slightly more light than the left. To avoid uneven lighting in the future, a measure of mean pixel intensity for each side of the face can be obtained prior to taping each subject. The lightbulbs or the reflective umbrellas can then be adjusted until the mean pixel intensities of each hemiface are equal.

A second approach is to adjust any lighting bias after the taping is completed. A computer program can be written to equalize the histograms of each half of the face such that the means would be roughly equal. This would eliminate the need to use statistical methods to account for a lighting confound. In this study, the subjective ratings were based on categorical measures, and therefore, statistically adjusting for the lighting bias was

problematic. Consequently, avoiding a lighting bias is
advantageous.

Another methodological concern was the size and quality
of the digitized images and the portion of the face included
in the image. Whether alone or in conjunction, these
factors were thought to have contributed to the anomalous
findings of the subjective ratings. Consequently, it is
recommended that enlarged pictures or slides, rather than
printed digitized images be developed and shown to the
subjective raters. Photographs or slides would likely
enhance the visual clarity which was lacking with the
printed digitized images.

Another option would be to produce video cuts so that
raters can view dynamic images, rather than static pictures.
Because the digitized analysis utilizes a dynamic process,
having raters view images from a dynamic method would be
more consistent. In the future, these recommendations could
be applied to the facial expressions of the subjects in this
study. For until impressionistic ratings of these subjects
are more in line with previous research, doubts may linger
about the generalizability of the results from the digitized
analysis.

To address the question of the facial window, future
studies might collect ratings from the whole face as well as
a limited portion of the face. The level of correlation
with each other as well as the agreement between each

subjective rating and the digitized data would address whether the area of the facial window affects subjective ratings. Such a study would also provide insights into the perceptual process of impressionistic ratings. The level of agreement between the subjective ratings and the digitized data might also determine the relative importance of movement quantity versus quality for human ratings of facial expressions.

Finally, a comparison of changes in mean pixel intensity was the method utilized for the digitized analysis in this study. Although apparently sufficient to capture expressive asymmetries, there exist today new methods of digital analysis that are currently being used to capture facial expressions. These models have not only been able to recognize faces at impressive rates of accuracy, but they have also been demonstrated to identify particular emotional expressions (Yuille, Cohen and Halliman, 1989; Matsuno, Lee, Kimura and Tsuji, 1995; Black and Yacoob, 1995; Lanitis, Taylor and Cootes, 1995; Essa and Pentland, 1995). In general, these models are oriented towards the areas of the face in which there are significant changes in shape and color. It is likely that they are more efficient and accurate in their measurements of expressive asymmetries. Future research examining the intensity of facial expressions require both subjective and more objective ratings. These new models may prove to be critical for

bringing a more quantitative approach to this line of research.

APPENDIX

PRIOR RESEARCH ON LATERALITY OF POSED
EMOTIONAL EXPRESSIONS BY NORMALS

Study	Subjects				Procedure		Emotions			Measures	Present	Results
	#	age	%male	%RH	Elicit	Raters	±	=	n			
Sackeim et al (1978)*	14		50		Muscle mimicry	86	1	4	1	7 pt intensity	Comp Slides	L-bias
Campbell (1978)	9		56	100	Command	24	1		1	Forced choice	Comp Photos	tendency L-bias
Campbell (1979)	24		82	0	Command	14	1		1	Forced choice	Comp Photos	L-bias happ R-bias relx
Schwartz et (1979)	20	21	50	100	Command	--	2	2	1	EMG	-----	Fem: L-bias corgt only
Rubin & Rubin (1980)**	20	9	50	50	Command	30	1	2	1	Forced choice	Comp Photos	Weak L-bias Effect > RH
Borod & Caron (1980)	51	39	40	60	Command	3 (conf)	3		6	15 pt intensity	Still Video	L-bias; M>F for neg
Ekman et al (1981)	36	ch			Muscle mimicry	1 tr	1	3	1	FACS	Video	Weak L-bias
Heller & Levy (1981)	9		100	56	Posed & Spont	24	1			Forced choice	Chim Tach	L-bias
Borod et al (1981)	48	39	40	60	Sent & Mimicry	3	3		6	15 pt intensity	Video	L-bias
Cacioppo\Pett (1981)	4	act	100	100	Command	50	1		2	7 pt emot, int	slides	R-bias neut & thoughtl
Sirota\Schwar (1982)	26	20s	0	100	Command	--	1		1	EMG	-----	No posed effect

* - Sackeim et al. erroneously reported happy to be posed, rather than spontaneous
** - most subjects were unable to produce 1 of the negative expressions (anger)

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Study	Subjects #	age	%male	%RH	Procedure Elicit	Raters	Emotions +	=	n	Measures	Present	Results
Borod & Koff (1983)	37	col	50	100	Posed & Spont	3/5	2	2	5	15 pt asymmetry	Video	L-bias uncor w/ mobility
Borod et al (1983)	37	col	50	100	Command Pictures	3 tr	2	2		7 pt int, 15 pt asym & category	Video	M: L-bias; F: + R-bias − L-bias
Dopson et al (1984)	23	col	40	100	Command	34 tr	1	1		7 pt express	Comp Photos	Weak L-bias
Hagar & Ekman (1985)	33	27	0	100	Command	1 tr	1	4	9	FACS	Video	Noneml: mix Emtl: L-bias zygoma only
Braun et al (1988)	28	24	50	83	Command	30	1	4	1	Forced choice	Comp Opasc	Sad: R-bias Rest: L-bias
Borod et al (1988)	16	59	100	100	Command Mimicry	2 tr	3	5	1	7 pt intensity	H/Face Vid-St	L-bias
Wylie\Goodale (1988)	35	21	46	49	Multiple	--	1			Marker movements	Digitl Image	No posed effect
Caltagiron et (1989)	28	56		100	Command	1tr/2	1	4		FACS Appropria	Video	No posed effect
Borod et al (1990)	21	60	58	100	Command	4 tr	3	4		15 pt asymmetry	Still Video	L-bias
Gazzaniga/Smy (1990)	2		100	100	Command		1			Asymmetry	Video	No posed effect
Moreno et al (1990)	90		0	100	Command	3 tr	2	2	1	7 pt intensity	Comp Photos	All ages L-bias

Study	Subjects #	age %male %RH	Procedure Elicit	Raters	Emotions ± = n	Measures	Present	Results
Mandal et al (1995)	10		Posed	35/35	1 1	7 pt intensity	Comp Photos	Hi intens: R-bias Lo intens: L-bias

Abbreviations: RH – right-handed, L – left, R – right, col – college, tr – trained, M – male, F – female, int – intensity, asym – asymmetry, Chim – chimeric, Tach – tachistoscope, opasc – opascope, Comp – composite, H/ – Hemi, Vid – video, st – still, emot – emotionality, - – negative, + – positive, emtl – emotional, express – expressivity, present – presentation, conf – conference, act – actors, appropria – appropriateness, pt – point, hi – high, lo – low, n – neutral, elicit – elicitation, intens – intensity, sent – sentence, spont – spontaneous, ch – children, Photos – photographs, happ –happy, relx – relaxed, neut – neutral, corgt – corrugator, neg – negative, thoughtl – thoughtful, uncor – uncorrelated, Digitl – Digital, w/ – with, zygoma – zygomatic, Pett – Petty, Schwar – Schwartz, Caltagiron – Caltagirone, Smy – Smylie

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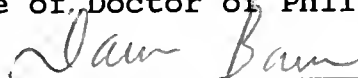Sirota, A.D. & Schwartz, G.E. (1982). Facial muscle patterning and lateralization during elation and

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BIOGRAPHICAL SKETCH
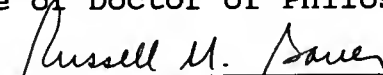
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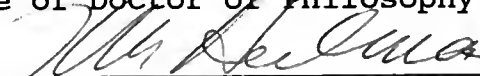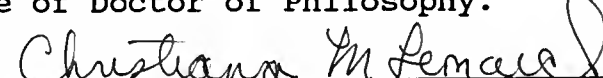
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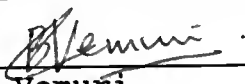
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This dissertation was submitted to the Graduate Faculty of the College of Health Professions and to the Graduate School and was accepted as a partial fulfillment of the requirements for the degree of Doctor of Philosophy.
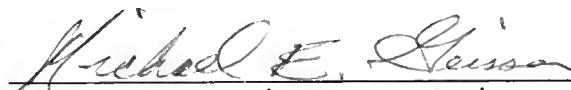
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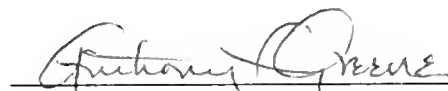
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August, 1993

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